JPL D-6226, Version 2001.02

Microdevices Laboratory

Safety Manual:

Operations, Policies, and

Procedures Plan

Process: Provide Microdevices Laboratory Services

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Review Cycle: 24 months
Next Review Due Before: July 3, 2003

Note that the electronic on-line version of this manual found at http://mdlwww under the safety banner is always the latest official version. Paper hardcopies of the MDL Safety Manual are for reference only.

CHANGE HISTORY:

Effective Date: July 3, 2001

Revision Number: 2001.02

Description: This is a revised document. Minor corrections, updates, links and additions have been made. The version number has been updated. Due to internal JPL reorganizations, the section number and name associated with MDL management has been changed throughout the document from the "Device Research and Applications Section (346)" to the "Space Microsensors Technology Section (384)". References to the "Section 346 Annual Safety Training" have been revised to read "Section (384 & MDL) Annual Safety Training". Added "Next Review Cycle Due Before:" date in "Approval Page (document change history)". Updated "Table of Contents" including: a) Inserting the location of "Table of Contents" for hardcopy bound versions; expansion of descriptor of "Approval Page (document history)" to "Approval Page (document change history)"; b) Change of title in Sec. 2.3 from "SPACE MICROELECTRONICS DEVICE R&D FOCUS" to "SPACE MICROSENSORS TECHNOLOGY R&D FOCUS" in order to correspond with new section designator (also done in body of document); c) Added missing subsections in Sec 10; d) Updated title in Section 15.1; and e) Correlated and updated page numbers with hardcopy print-out. In Sec. 2.1, added the "B-2" classification to the term "conventional B-2 laboratory" and added pointers to the definitions of "B-2 Areas" and "H-6 Areas" found in Sec. 5.10 and 5.21, respectively. These definitions were expanded to indicate the dates of the codes under which MDL was designed and brought into compliance and operation. Updated R&D Focus categorizations in Sec 2.3 to align with current organization structure. Revision numbers were removed from the document title descriptors in Sec. 4.14 and Sec. 4.17. Minor updates were made to the description of the "Section (384 & MDL) Annual Safety Training" in Sec. 6.4.2.1: a) The "Medical Surveillance Program" sub-topic was removed from the course contents under "Legal Requirements, Rights and Responsibilities, including:" as this program is currently under review at JPL and is in transition; b) "Ergonomics" is added and explicitly called out as a sub-topic under "Non-technical Area Safety"; c) The "Electrical Safety" topic was expanded to include "and :Lockout / Tagout"; and d) Specific topics under "Chemical Hazards" were merged and identified as "Presentations from various MDL processors". The reference link to "MOVPE filter change out procedures" in Sec. 9.6 was changed to the more generic "MOCVD / MOVPE servicing procedures" to allow a grouped link to these expanding and numerous procedures. Clarified statement under Sec. 10.26, "Silane", from "Evacuate piping and systems with inert gas before introducing silane" to "Evacuate, purge with inert gas, and evacuate again before introducing silane". Syntax in Sec. 11.5.1 and Sec. 11.5.2 was improved. We note that hardcopy "snapshots" of this document JPL D-6226, ver. 2001.02, utilized in the Section (384 & MDL) Annual Safety Training include copies of the linked procedures in Sec. 11.8 (Gas Delivery Checklist, MDL Gas Bunker Procedures) and Sec. 11.9 (MDL Hydrogen Bunker Procedures). The greatest changes occured in Section 15 and deal with MDL User Classifications and requirements. The title of Sec. 15.1 was changed from "ACCESS" to "ACCESS AND USER CLASSIFICATIONS". Sec. 15.1.1.1, "MDL User Classifications" was extensively modified, expanded and clarified. Sec. 15.1.1.1.1 was expanded to include the "Senior" designation and the syntax improved. Sec. 15.1.1.1.4 was divided into subsections for clarity and the criteria for elevation to the senior status was defined in Sec. 15.1.1.1.4.3 . Sec. 15.1.1.1.4.4 was added which further delineates the "Senior Processor" classification and indicates how it differs from the job family classifications utilized by JPL to denote technical knowledge, experience, and responsibility. The "Senior Processor Lead" classification status previously defined in Sec. 15.1.1.1.5, ver. 2001.01 was eliminated

and merged with the "Senior Processor" classification status due to the stringent requirements and criteria associated with the "Senior Processor" status. Sec. 15.1.1.1.4.1, ver. 2001.01 concering the "Senior-100" classification was elevated to Sec. 15.1.1.1.5 in this version 2001.02 for clarity. Mentor responsibilities under Sec. 15.1.1.2 ver. 2001.01 was split out into a subsection 15.1.1.2.1 in this version 2001.02 for clarity and expanded. Sec. 15.1.1.4 was modified slightly for clarity and the custodian of record defined as the MDL Safety Engineer. Appendix 2 was modified to correctly reflect the extent of the H-6 area (incorrectly shown as extending to 302-101A,B,C, & D areas in ver. 2001.01). Appendices 4,5,and 11 were updated with respect to section references and personnel changes.

Effective Date: March 19, 2001

Revision Number: 2001.01

Description: This is a revised document. Minor corrections, updates, links and additions have been made. A major typographical error in the JPL document number has been discovered (present since Rev. C) and corrected. It was incorrectly listed as JPL D-6225. It and references to it (see Title page, Approval page, Table of Contents, and Sec. 3.1.12) have been revised to reflect the correct number JPL D-6226. The Custodian of Record and Sec 346 Manager have been updated in the approval page. Notices (disclaimers) defining the electronic version at http://mdlwww as being the only official version of this document and statements that paper hardcopies of the MDL Safety manual as being for reference only have been added to the title page and the authorization/change history page. (They already existed at the website). ACGIH, HAZCOM (replacing HCP = Hazard Communication Program), and RCU were added to the "List of Acronyms" and updated elsewhere in the document (i.e. Sec. 6). Cleanroom classifications have been amended to reflect new ISO designations (i.e. Class 10 = ISO 4; Class 100 = ISO 5; Class 100,000 = ISO 8). References to the "MDL Configurational Control Group" have been revised to reflect the correct reference of "MDL Configuration Control Group" (See Section 3 and Section 7). Wording in Sec. 3.1.5 was amended to reflect the Section 346 Manager has "control over" instead of "control of" most operations. Fig. 3.1 has been revised eliminating FTE allocations and updating organization numbers (i.e. JPL OHS organization changed from 198 to 194). The reference to "all hazardous chemicals" has been amended to read "hazardous chemicals" in Sec. 3.4.4. The definition of buddy system in Sec. 3.5.1 was modified from "having two persons within eye contact of each other at all times", to "having two persons within contact of each other at all times". This was also amended in section 14.3.2.1 . Sec. 3.7, "Disciplinary Actions", has been completely revised with new wording and links placing it in conformance with the JPL progressive discipline policy, Doc. # 11004. Wording in Sec. 3.8.1.4 was revised to allow a greater than 3 month extension to meet medical requirements without removal from work at the discretion of MDL management. The description for Sec. 4.9, "Facilities Service Request Form (JPL #0313-S R 01/99)", was updated to reflect the retirement of this hardcopy form and replacement by an electronic service request process. The descriptor for Sec. 4.10, "Hazardous Waste Disposal Form (JPL # 2799-1 R 04/99)" was updated to reflect both the form number change to JPL # 2799-S, and the new ability to access these forms with the required unique number and bar code at JPL Electronic Forms. The requirement in Sec. 4.11 for signing in the Maintenance and Facilities sign-in logs was amended with "who are doing service work in MDL". The descriptor in Sec. 4.14 was modified to correctly reflect that it is the cognizant MDL group supervisor (and not the cognizant group supervisor) who assigns a qualified cleanroom contact (mentor). A definition of MDL Group Supervisor was also provided. Clarifications were also made to the wording defining the mentors responsibilities. "Periodic posting" was added to the custodian (of record) duties in the description of Sec. 4.15, "MDL H-6

Area Access List". Sec. 4.16, Mishaps Reports Form (JPL 0554 S) requirements for filling out the form was updated to reflect damage amounting to $1,00 or more instead of $50.00 or more. The "Request for Use of MDL Machine Shop Form (MDL 1736 R5/00)", described in Sec. 4.21 and displayed in Appendix 18 has been revised and retitled as "Request for Direct Use of Machine Shop Equipment as an Authorized MDL User Form (MDL 1736 R 1/01)". The descriptor and form were revised to reflect the new use for this form including approval for after hour key access. Slight improvements to the definitions of Sec. 5.1, "Acid", Sec. 5.5, "Agents that act on blood", Sec. 5.11, "Carcinogen", Sec. 5.38, "pH", and Sec. 5.39, "Physical Hazard" have been made. The definition of REL, Recommended Exposure Limit, a terminology utilized by NIOSH was added as Sec. 5.4.2 and subsequent terminology numbering incremented. All references to outside regulatory documents were reviewed for accuracy and currency. The reference to the California Administrative Code (CAC) in Sec. 6.1.3 was replaced with the correct and current reference of the California Code of Regulations. "For the purposes of labeling" was added to the definition of container in Sec. 6.2. The wording relating to training for JPL Wardens, Machine Shop Operators and Gas Handlers has been changed to recommend rather than require specific training in Sec. 6.4.2.2, Sec. 6.4.2.3, and Appendix 13. An introductory statement defining applicability was added to Sec. 6.4.3, "Outside Contractor Training". The contractor responsibility of supplying the JPL OSO and MDL Safety Engineer with the contractor's company's Safety Plan was explicitly added to Sec. 6.4.3.2, "Contractor's Responsibilities". Sec. 7.4.2 has been reworded, adding the option of presenting the documentation material, and eliminating the word "preliminary" in the review process and adding a reference and link to the definition of the Configuration Control Group in Sec. 3.2.2. Additions to Sec. 8.3, "Air Handlers", have been made describing the addition of Air Handler 6 (AH6) for the cleanroom expansion in 302-101A and 302-101B. Sections 8.4.3.7 and 16.6.2.7 were expanded to indicate hose cabinets are to be accessed and utilized by Fire Dept. (trained) personnel only as per NASA directive. Emergency numbers were updated to reflect the alternate cellular phone number 393-3333 to connect with JPL specific local emergency responders (Sec. 8.4.3.11, Sec. 16, Appendix 13, and Appendix 19). Sections 9.1.4.4 and 15.2.10, which cover special labeling requirements for the retention of chemicals beyond their normal expiration dates, were modified to add wording which clearly indicates this retention is an exception to standard practices requiring approval by MDL management. Sec. 9.18 was expanded to indicate both acid and corrosive (and not just acid) operations are to be performed on the white polypropylene wet processing stations (benches). The adjective "specular" was added to "reflective objects" in Sec. 9.2.3. "Or designated alternate" was added to Sec. 9.3.1 concerning the review and approval of chemical orders. Wording was added to Sec. 9.2.4.1 to indicate that respirators issued by the MDL Safety Engineer is in conjunction with the JPL OSO. A chemical compatibility table has been added as Appendix 20 and referenced in Sec. 9.4.6. A note was added to Sec. 9.5.1.3 indicating that cleanroom compatible label materials must be utilized within the certified MDL cleanroom areas. Sec. 9.5.1.13 was expanded to allow hazardous waste containers to be open during both filling and emptying operations (and not just filling operations). An introductory disclaimer and reference sources were added to Section 10, "Specific Chemical Hazards". In addition, entries in Section 10 were reviewed and updated. Clarification updates for arsine (Sec. 10.4), boron trichloride (Sec. 10.5), and hydrogen sulfide (Sec. 10.18) were provided. New entries for carbon monoxide (Sec. 10.7) and ethylene (Sec. 10.12) (gases utilized in carbon nanotube growth processes) were incorporated into the document. "Cryogenics" was expanded to "JPL Gas and Cryogenics" for clarification in Sec. 11.3.3. Sec. 11.6.8 was expanded to include reasons to avoid the backseating of cylinder valves. Sec. 12.5.1 concerning circuit breakers was expanded to include the statement "proper securing devices are available through the MDL Safety Engineer". Sec. 12.5.4 was expanded to include reasons and recommended practices for grasping electrical equipment. The reference in Sec. 12.5.14 to SPI 4-08-02 "Use of Kitchen-Type Appliances" was deleted and

updated with a link to the new reference "General Fire Safety Requirement" , Doc. # 45352, found on JPL's DMIE system. Sec. 13, "Laser Safety", was updated to be inconformance with the newly issued JPL Laser Safety Program (DMIE-45393). An introductory statement was added to Sec. 13. The JPL document reference in Sec. 13.1.3 was updated and linked to the current "Laser Hazards and Operations Safety Manual", Doc. # 1516 on JPL's DMIE system and the newly published "Laser Safety Program", DMIE Requirement Document #45393. Sec. 13.1.3 was expanded to list requirements necessary to operate a laser at JPL from DMIE documents. A new entry, Section 13.4, "Laser Warning Labels", defining labeling requirements for lasers fabricated and packaged by MDL taskwork, was added to the document. Section 14 on Machine Shop Safety has been extensively revised to reflect the relocation of the majority of the machine shop equipment from 302-149 to the bldg. 103 Tech Shop under the cognizance of Section 357. The statement in Sec. 14.3.1.2 "MDL personnel DO NOT teach the use of shop tools, but only familiarize the user with basic equipment configuration and verify that the user's performance demonstrates that he/she has the basic skills to operate the machinery." has been deleted and training details left to the discretion of the the shop coordinators / cognizant engineers. Sec. 15.1.1.1 was expanded to provide clarification on cleanroom classifications including the MDL Senior Processor, the MDL Senior-100, and the MDL Senior Processor Lead classifications. The definition of an MDL cleanroom mentor in Sec. 15.1.1.2 was reworded to clarify that mentoring practices apply to the entire H-6 area and not just the cleanroom proper areas. Sec. 15.1.1.3 on mentoring was expanded to include the statement: "This oversight will continue until the trainee / new hire transitions to the "Fully Qualified" status." "Trainer" was expanded to read "cognizant engineer or designated trainer" for clarification in Sec. 15.2.4. The MDL Equipment Engineer was explicitly added to the reporting list for equipment problems in Sec. 15.2.8. An introductory statement was added to Section 16, "Emergencies", placing this MDL specific section in context with overall JPL emergency plans as defined in JPL's Multihazard Emergency Response Plan, Doc. # 28012, on the DMIE system. A link was established. Sec. 16.4.1, "Hazardous Gas Releases" and Appendix 19, "Microdevices Laboratory Safety Guidelines for JPL Facilities/Maintenance, Outside Contractors and Visitors," were revised to indicate that building evacuations are initiated through the building fire alarm system if sufficiently high alarm levels are reached. A statement that "Evacuation assembly points have been reviewed to be at safe, upwind locations under most conditions" has been added to Sec. 16.4.1 and Appendix 19. Sec. 16.5, "Accident Investigation", was expanded to include directives covering the recognition, collection and preservation of physical evidence. Expansions were also added to Sec. 16.5 concerning responsibilities and mishap reporting with references and links. The introductory statements in Sec. 16.6, "Building Shutdown Procedures", were expanded for clarification. Sec. 16.6.7.3, "Seismic Detection System", was updated to reflect the addition of a third centralized JPL seismic monitoring system recently installed in MDL (and elsewhere throughout JPL). The maps in the appendixes were reviewed for accuracy and consistency and updated to reflect the cleanroom expansion into 302-101 and the existence of 302-102A. The sample IOM in Appendix 4 was corrected to reflect the MDL Manager's approval for H-6 access and updated with current personnel. Appendix 11, "MDL Management, Warden and Gas Handler Roster", was updated. The references in Appendix 12 were reviewed and updated.

Appendix 20, "Useful Phone Numbers", was renumbered as Appendix 21 and updated.

Effective Date: May 18, 2000

Revision Number: 2000.02

Description: This is a revised document. Minor corrections, updates, links and additions have been made. References to the JPL Safety Operations Section (SOS) have been updated to reflect the current name, the JPL Occupational Safety Office (OSO). A "Custodian of Record" for the official electronic version of this document has been added to the Approval Page (document history page). References to "JPL Operational Safety Reviews (OSRs)" have been updated to reflect their new name: "JPL Pre-Operational Safety Reviews (Pre-OSRs)". References to the previous class 1000 cleanroom bays 302-134 and 302-136 have been updated to reflect their new certifications as class 100 cleanrooms. References to the JPL emergency number 3-3333 have been amended to reflect the new 911 emergency number. Figure 3-1 has been updated to reflect the new organizational structure and name of the JPL Occupational Safety Office and to reflect a restructuring of the MDL Safety Maintenance Technician support. The MDL Authorization Form defined in Section 4.14 and provided in Appendix 5, has been assigned a form number and version number: MDL 41399 R 5/00. The MDL Machine Shop Form defined in Section 4.21 and provided in Appendix 18, has been assigned a form number and version number: MDL 1736 R 5/00. The "Custodian of Record" for authorized machine shop users has been transferred from the MDL Safety Engineer to the MDL Machine Shop Coordinator / Cognizant Engineer (reference Section 4.21 and Section 14.2.2). A description of the new JPL Chemical Hygiene Plan has been provided in Sec 4.22. A minor expansion to the definition of pH was made in Section 5.38. An updated description of the contents of the Section 346 Annual Safety Training has been provided in Sec 6.4.2. Expanded clarification details concerning the Organizational elements involved in the configurational control process was provided in Section 7.2.1. The "Process cooling water system" was removed from the listing of specific elements of the MDL Life Safety System in Section 7.3.8 since it is covered in Section 7.3.6 and is not part of the MDL Life Safety System. The Pendant Alarm System was added to the listing in Section 7.3.8. The requirement for goggles in Sec. 9.2.2, "Cryogenic operations", has been amended to require "Eye protection" with "(goggles recommended)" to be consistent with Section 11.5. The requirement for designated scheduled change-outs for respirator cartridges (a new legal requirement) has been added to Sec 9.2.4.10. Section 9.5.6, "Specific Hazardous Chemical Operations" has been retitled "Procedures for Specific Hazardous Chemical Operations" and raised to a separate heading: Section 9.6, and new procedures with electronic links provided. A clarification comment was added to Section 10.1 on acetylene indicating "(Acetylene is shipped dissolved in acetone)". An expanded description of the health effects of exposure to high and low amounts of Oxygen was added to Section 10.19. Additional comments on EGMEA and PGMEA photoresists with links were provided in Section 10.23 on the Chemical Hazards of Photoresists. Synonyms for Silane were provided in Section 10.24. Links to Specific Gas Bottle Delivery Procedures have been added to Sections 11.8 and 11.9. General instructions for laser safety documentation and training were added in newly added Sections 13.1.3 and 13.1.4. Explicit gowning requirements and procedures for H-6 class 100,000 areas have been spelled out in Section 15 (i.e. Sections 15.1.4, 15.1.6, 15.17, 15.1.8, and in newly added Sections 15.1.9, and 15.1.10). Special labeling requirements for in-use chemicals which researchers desire to be retained beyond their normal expiration dates is described in Section 15.2.10 (and referenced in Section 9.1.4.4). The 3rd UPS system for the new JEOL E-Beam Lithography system in 302-101B has been noted in Sec 16.6.4.3. Alarm threshold levels for MDL's Life Safety Systems has been documented in Sections 16.6.7.1 and 16.6.7.2. The information documented in the MDL Certification Record (Appendix A5, page 2) is now available electronically at http://mdlwww.jpl.nasa.gov/people/userlist. Appendix 16, "CDO Maintenance Procedures" has

been re-titled "CDO and Wet Scrubber Maintenance Procedures" and has been expanded to include CDO Overpressurization Capture Ring use instructions (Appendix A16, Sec. 1.7) and wet scrubber maintenance procedures defining solution change-out procedures (Appendix A16, Sec. 2). Appendix 20, "Useful Phone Numbers" has been updated. In addition, maps in the appendices (A1, A2, A3, A12, & A19) have been updated to reflect the class 100 cleanroom expansion into 302-101 to house the new JEOL E-Beam Lithography system and the appendices have been highlighted to allow greater clarification of the information being conveyed.

Effective Date: February 28, 2000

Revision Number: 2000.01

Description: This is a revised document. Appendix 11 (MDL Management, Warden and Gas Handler Roster) updated. Gas Handlers are now listed in a separate table. MDL public address number changed from 162 to 168.

Effective Date: June 2, 1999

Revision Number: 1999.04

Description: This is a revised document. Appendix 11 (MDL Management and Warden Roster) updated.

Effective Date: May 6, 1999

Revision Number: 1999.03

Description: This is a revised document. Appendix 11 (MDL Management and Warden Roster) updated.

Effective Date: April 13, 1999

Revision Number: 1999.02

Description: This is a revised document. It retires the "MDL Authorization Form for Non-Section 346 Personnel (version 3/22/99)" and merges it with the "MDL Authorization Form for Section 346 Personnel (version 3/22/99)" to create a single "MDL Authorization Form (version 4/13/99)" for all MDL laboratory users (Appendix A-5). This form is to be completed annually. References within the document to these forms have been updated. In addition, the Cleanroom Policies have been expanded (Sections 15.1.1.1 through 15.1.1.4) to provide for "Trainee/ New Hire" and "Fully Qualified" statuses and delineate the transition process including an oral cleanroom practical examination and mentor oversight.

Effective Date: March 22, 1999

Revision Number: 1999.01

Description: This is a revised document. It updates documentation and procedures to reflect current practices and organization and incorporates minor corrections to spelling errors, etc. Specific substantial changes are 1) Removal of references to the disbanded MDL Safety Advisory Board with duties/responsibilities transferred to the MDL Safety Engineer and JPL SOS; 2) Medical policy updated reflecting requirement of annual medical surveillance for all H-6 processors; and 3) The addition of a new requirement for ALL MDL users to fill out an authorization form annually (includes a new form and modification of old form). Contractor/ visitor safety training documentation forms have been included in the appendices. In addition, additional entries and updates to Sec. 10, Specific Chemical Hazards, has been included. Sections documenting procedures for the purchasing of cleanroom supplies and user requests and services have been added to Sec. 15. There have also been some minor formatting changes in effecting the transition from hardcopy to this electronic format. Some expansion in the listing of forms has been incorporated in Sec. 4 for completeness (even though this adds some minor redundancy in content). Furthermore, some minor additions concerning records and documents (e.g. specific information concerning custodians, location of records, and duration) have been made to provide clarity and avoid confusion.

Effective Date: February, 1999

Revision Number: 1999.00

Description: This is a new electronic document. It places in electronic form the legacy hardcopy document JPL D-6225, Rev. A noted below. Basic processes, procedures and policies are unchanged since inception, so that there are no substantive changes. {Changes and updates to this electronic version are required (reflecting evolution in practices and organization since this earlier version as well as information included in Rev. C) and will be incorporated in the next revision.}

Effective Date: January, 1998

Revision Number: C

Description: This is a hardcopy legacy document. There were no substantial changes except wording requiring "Mandatory" annual H-6 medical surveillance was deleted. Appendices were also updated. Some minor corrections to typographical errors and updates of chemical information was included. (Note that there was no JPL D-6226, Rev B.)

Effective Date: September, 1992

Revision Number: A

Description: This is a new hardcopy document of the original release. It was the first hardcopy mass distribution of the information to the user community. It merged the Microdevices

Laboratory JPL/MDL Configuration Control Plan JPL D-6593, and the Microdevices Laboratory Emergency Response Plan JPL D-6254 into this document and allowed D-6593 and D-6254 to be retired. It also updated and expanded relevant information related to the documents, safety policies, practices and procedures to be employed within the Microdevices Laboratory (MDL).

Effective Date: August, 1989

Revision Number: --

Description: This is a new hardcopy legacy document (previous versions were unapproved drafts). It documents safety policies, practices and procedures to be employed within the Microdevices Laboratory (MDL).

Jet Propulsion Laboratory

California Institute of Technology

MDL SAFETY MANUAL

JPL D-6226, Version 2001.02

Jet Propulsion Laboratory
California Institute of Technology

TABLE OF CONTENTS

[Note that the leading numbers are the paragraph numbers and the trailing numbers are the page numbers with the section when printed]

Title Page

Approval Page (document change history)

TABLE OF CONTENTS

LIST OF ACRONYMS

1.0 SCOPE — Section 1

2.0 OVERVIEW — Section 2

- 2.1 DESCRIPTION — Page 1
- 2.2 TECHNICAL PROCESSING FACILITIES — Page 1
- 2.3 SPACE MICROSENSORS TECHNOLOGY R&D FOCUS — Page 3

3.0 MDL ADMINISTRATIVE AND BUILDING SAFETY POLICIES — Section 3

- MDL SAFETY MANAGEMENT RESPONSIBILITIES AND ORGANIZATION — Page 1
- MDL SAFETY OVERSIGHT — Page 2
- BUILDING SHIFTS AND HOURS OF OPERATION — Page 4
- ACCESS AND AUTHORIZATION — Page 5
- BUDDY SYSTEM — Page 7
- CHANGES, MODIFICATIONS, ADDITIONS, AND DELETIONS — Page 8
- DISCIPLINARY ACTIONS — Page 8
- MEDICAL AND PHYSICAL EXAMINATIONS — Page 10
- TRAINING POLICY — Page 11

4.0 DOCUMENTS, LOGS, AND FORMS —Section 4

- 4.1 AFTER-HOURS AUTHORIZATION LIST — Page 1
- 4.2 AFTER-HOURS SIGN-IN LOG — Page 1
- 4.3 CHEMICAL INVENTORY FORMS — Page 1
- 4.4 CLEANROOM ACCESS LIST — Page 1
- 4.5 CLEANROOM SIGN-IN LOG — Page 2
- 4.6 EMERGENCY SHUTDOWN PROCEDURE (ESP) — Page 2
- 4.7 EQUIPMENT OPERATING SIGNS — Page 2
- 4.8 EQUIPMENT OPERATIONS LOGS — Page 2
- 4.9 FACILITIES SERVICE REQUEST FORM — Page 2

- 4.10 HAZARDOUS WASTE DISPOSAL FORM (JPL # 2799-S) — Page 3
- 4.11 MAINTENANCE AND FACILITIES SIGN-IN LOG — Page 3
- 4.12 MATERIAL SAFETY DATA SHEETS — Page 3
- 4.13 MDL AUTHORIZATION FORM FOR NON-SECTION 346 PERSONNEL (Retired 4/13/99) — Page 6
- 4.14 MDL AUTHORIZATION FORM (MDL # 41399) — Page 5
- 4.15 MDL H-6 AREA ACCESS LIST — Page 5
- 4.16 MISHAP REPORT FORM (JPL # 0554 S) — Page 5
- 4.17 PRE-OPERATIONAL SAFETY REVIEW (Pre-OSR) (JPL # 0284) — Page 6
- 4.18 MDL SAFETY MAINTENANCE PLAN AND SERVICE MANUAL (JPL D-6542) — Page 6
- 4.19 MDL FACILITIES MAINTENANCE PLAN (JPL D-6707) — Page 7
- 4.20 MEDICAL SURVEILLANCE REQUEST FORM (JPL2633-S) — Page 7
- 4.21 REQUEST FOR DIRECT USE OF MACHINE SHOP EQUIPMENT AS AN AUTHORIZED MDL USER (MDL # 1736 R 1/01) — Page 7
- 4.22 JPL CHEMICAL HYGIENE PLAN (CHP) — Page 7

5.0 TERMINOLOGY —Section 5

6.0 HAZARD COMMUNICATION PROGRAM — Section 6

- 6.1 PERSONNEL RESPONSIBILITIES — Page 1
- 6.2 CONTAINER LABELING — Page 1
- 6.3 MATERIAL SAFETY DATA SHEETS (MSDSs) — Page 2
- 6.4 INFORMATION AND TRAINING — Page 3

7.0 CONFIGURATION CONTROL —Section 7

- 7.1 SCOPE — Page 1
- 7.2 CONFIGURATION CONTROL GROUP CHARTER — Page 1
- 7.3 FACILITY AND EQUIPMENT MODIFICATIONS AND HAZ-OP REVIEWS — Page 2
- 7.4 IMPLEMENTATION OF CHANGES, ADDITIONS, DELETIONS, AND MODIFICATIONS — - Page 3

8.0 FACILITIES AND UTILITIES — Section 8

- 8.1 CENTRAL UTILITIES — Page 1
- 8.2 EFFLUENT SYSTEMS — Page 1
- 8.3 AIR HANDLERS — Page 2
- 8.4 SAFETY SYSTEM — Page 3

9.0 CHEMICAL POLICIES — Section 9

- 9.1 POLICIES — Page 1
- 9.2 PERSONAL PROTECTIVE EQUIPMENT (PPE)— Page 2
- 9.3 REQUISITIONS — Page 5
- 9.4 DISTRIBUTION AND STORAGE — Page 6
- 9.5 HAZARDOUS WASTE HANDLING — Page 6
- 9.6 PROCEDURES FOR SPECIFIC HAZARDOUS CHEMICAL OPERATIONS — Page 10

10.0 SPECIFIC CHEMICAL HAZARDS — Section 10

Reference List — Page 1

- 10.1 ACETYLENE (C_2H_2) — Page 2
- 10.2 AMMONIA (NH_3) — Page 3
- 10.3 ARSENIC (As) & ARSENIC OXIDES (AsOx) — Page 3
- 10.4 ARSINE (AsH_3) — Page 4
- 10.5 BORON TRICHLORIDE (BCl_3) — Page 5
- 10.6 BROMINE SOLUTIONS — Page 6
- 10.7 CARBON MONOXIDE (CO) — Page 6
- 10.8 CHLORINE (Cl_2) — Page 7
- 10.9 DIBORANE (B_2H_6) — Page 7
- 10.10 DICHLOROSILANE (SiH_2Cl_2) — Page 8
- 10.11 DIMETHYL ZINC (DMZ) — Page 9
- 10.12 ETHYLENE (C_2H_4) — Page 9
- 10.13 FLUORINE (F_2) — Page 9
- 10.14 HYDROGEN (H_2) — Page 10
- 10.15 HYDROGEN CHLORIDE (HCl) — Page 11
- 10.16 HYDROGEN FLUORIDE (HYDROFLUORIC ACID (HF)) — Page 11
- 10.17 HYDROGEN SELENIDE (H_2Se) — Page 12
- 10.18 HYDROGEN SULFIDE (H_2S) — Page 13
- 10.19 METHANE (CH_4) — Page 14
- 10.20 NITROUS OXIDE (N_20) — Page 14
- 10.21 OXYGEN (O_2) — Page 15
- 10.22 OZONE (O_3) — Page 16
- 10.23 PHOSGENE ($COCl_2$) – (By-product of certain operations – e.g. pump operations involving chlorine) — Page 16
- 10.24 PHOSPHINE (PH_3) — Page 17
- 10.25 PHOTORESISTS — Page 18
- 10.26 SILANE (SiH_4) — Page 19
- 10.27 TCE – TRICHLOROETHYLENE (C_2HCl_3) — Page 20

11.0 COMPRESSED GAS CYLINDER AND CRYOGENIC DEWAR SAFETY —Section 11

- 11.1 COMMON HAZARDS — Page 1
- 11.2 SAFETY DEVICES — Page 1
- 11.3 RECEIVING — Page 2
- 11.4 STORAGE — Page 2
- 11.5 PERSONAL PROTECTIVE EQUIPMENT (PPE) FOR CRYOGENIC OPERATIONS — Page 2
- 11.6 HANDLING — Page 3
- 11.7 GENERAL — Page 4
- 11.8 SPECIFIC TOXIC GAS BOTTLE DELIVERY PROCEDURES — Page 4
- 11.9 SPECIFIC HYDROGEN DELIVERY PROCEDURES TO HYDROGEN GAS BUNKER — Page 4

12.0 ELECTRICAL SAFETY AND LOCKOUT POLICY — Section 12

- 12.1 SCOPE — Page 1
- 12.2 RESPONSIBILITIES — Page 1
- 12.3 DEFINITIONS — Page 1
- 12.4 LOCKOUT / TAGOUT PROCEDURE — Page 2
- 12.5 ELECTRICAL SAFETY — Page 3

13.0 LASER SAFETY — Section 13

- 13.1 GENERAL — Page 1
- 13.2 LASER CLASSIFICATIONS — Page 2
- 13.3 LASER SAFETY POLICIES — Page 2
- 13.4 LASER WARNING LABELS — Page 3

14.0 MACHINE SHOP SAFETY — Section 14

- 14.1 APPLICABLE DOCUMENTS — Page 1
- 14.2 RESPONSIBILITIES — Page 1
- 14.3 SAFETY RULES — Page 2

15.0 CLEANROOM POLICIES — Section 15

- 15.1 ACCESS AND USER CLASSIFICATIONS — Page 1
- 15.2 MATERIALS AND EQUIPMENT — Page 6
- 15.3 INSTALLATIONS — Page 7
- 15.4 CLEANROOM MAINTENANCE — Page 8
- 15.5 PURCHASING OF CLEANROOM SUPPLIES — Page 8
- 15.6 USER REQUESTS AND SERVICES — Page 8

16.0 EMERGENCIES — Section 16

- 16.1 NOTIFICATION — Page 1
- 16.2 EMERGENCY CONTACTS — Page 2
- 16.3 EVACUATION — Page 2
- 16.4 RESPONSES TO SPECIFIC INCIDENTS — Page 3
- 16.5 ACCIDENT INVESTIGATION — Page 9
- 16.6 BUILDING SHUTDOWN PROCEDURE — Page 10
- 16.7 EMERGENCY PREPAREDNESS — Page 21

APPENDIXES

- A1 MDL FIRST FLOOR LAYOUT WITH EMERGENCY EQUIPMENT
- A2 H-6 AND LIGHT LAB AREAS (FIRST FLOOR)
- A3 CLEANROOM AREAS (FIRST FLOOR)
- A4 SAMPLE MEMO: CLEANROOM ACCESS
- A5 MDL AUTHORIZATION FORM
- A6 HAZARDOUS WASTE DISPOSAL FORM
- A7 EXPLOSIVE-FORMING ORGANIC PEROXIDES
- A8 EXPLOSIVE MATERIALS AND THEIR APPLICATIONS

- A9 UFC TABLE 51.105A, PERMITTED QUANTITIES OF HPM IN A SINGLE FABRICATION AREA
- A10 UFC TABLE 51.106B, MAXIMUM QUANTITIES OF HPM
- A11 MDL MANAGEMENT, WARDEN AND GAS HANDLER ROSTERS
- A12 EVACUATION ROUTES, ASSEMBLY AREAS, AND DRILL PROCEDURES
- A13 WARDEN RESPONSIBILITIES
- A14 MDL ALARM AND DETECTION POINTS
- A15 ROTARY VANE VACUUM PUMP FLUID CHANGE PROCEDURE
- A16 CDO AND WET SCRUBBER MAINTENANCE PROCEDURES
- A17 AHM GAS PLUMBING INTEGRITY VERIFICATION PROCEDURE
- A18 REQUEST FOR DIRECT USE OF MACHINE SHOP EQUIPMENT AS AN AUTHORIZED MDL USER
- A19 MICRODEVICES LABORATORY, SAFETY GUIDELINES FOR JPL FACILITIES/MAINTENANCE PERSONNEL, OUTSIDE CONTRACTORS, AND VISITORS (Rev 03/19/2001)
- A20 EXAMPLES OF INCOMPATIBLE CHEMICALS
- A21 USEFUL PHONE NUMBERS

LIST OF ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
AHM	acutely hazardous material
BIB	blocked impurity band
CCG	Configuration Control Group or Chemical Controls Group
CCR	California Code of Regulations
CDA	compressed dry air
CDO	(controlled) combustion-decomposition-oxidation unit
CFM	cubic feet per minute
CFR	Code of Federal Regulations
CHP	Chemical Hygiene Plan
CPR	cardiopulmonary resuscitation
CPU	central processing unit
CVD	chemical vapor deposition
DI	deionized (water)
DMIE	Define and Maintain the Institutional Environment
DNA	deoxyribonucleic acid
DOD	Department of Defense
DOT	Department of Transportation
EAO	Environmental Affairs Office
EBIC	electron-beam-induced current
ECR	electron cyclotron resonance
EMS	Energy Management System (See also SCS -- Staefa Control Systems)
EMO	emergency off
EPA	Environmental Protection Agency
ESP	emergency shutdown procedure
ESO	emergency shutoff
FAP	fire alarm panel
FDA	Food and Drug Administration
FIR	far infrared

FRP	fiberglass reinforced polyester (or plastic)
FSG	Flight Safety Group
GSSG	Ground Systems Safety Group
HAZCOM	Hazard Communication Program
Haz-Op	hazard operability (review)
HEPA	high-efficiency particulate air (filter)
HF	hydrofluoric (acid)
HGB	hazardous gas bunker
HMIS	Hazardous Materials Inventory Statement
HMMP	Hazardous Materials Management Plan (Business Plan)
HMRT	Hazardous Materials Response Team
HPM	hazardous production material
HVAC	heating, ventilation, and air conditioning
HWDF	hazardous waste disposal form
IDLH	immediately dangerous to life and health
ISG	Industrial Safety Group
JPL	Jet Propulsion Laboratory
JPLFD	JPL Fire Department
LEL	lower explosive limit
LFL	lower flammable limit
LPE	liquid phase epitaxial (reactor)
MBE	molecular beam epitaxy
MDA	MDA scientific, Inc. (hydride and mineral acid detector)
MDI	Monitor Dynamics, Inc. (safety monitoring supervisory system)
MDL	Microdevices Laboratory
MOCVD	metallo-organic chemical vapor deposition
MOVPE	metallo-organic vapor phase epitaxy
MSDS	materials safety data sheet
MWIR	mid-wavelength infrared
NEC	National Electrical Code
NFPA	National Fire Protection Association

NIOSH	National Institute of Occupational Safety and Health
OEIC	optoelectronic integrated circuit
OHS	Occupational Health Services
OMVPE	organo-metallic vapor phase epitaxy
OSHA	Occupational Safety and Health Administration
OSO	Occupational Safety Office
OSR	Operational Safety Review (see new designation of pre-OSR)
PA	public address
PCSI	Process & Cryogenic Services, Inc.
PEL	permissible exposure limit
PIV	post-indicator valve
PPE	personal protective equipment
PPU	preprocessor unit
Pre-OSR	Pre- Operational Safety Review
RCU	re-circulating unit
RF	radio frequency
RMPP	Risk Management (and Mishap) Prevention Plan
RNA	ribonucleic acid
RODI	reverse osmosis deionizer
RTU	remote terminal unit
SCAQMD	South Coast Air Quality Management District
SCBA	self-contained breathing apparatus
SCS	Staefa Control Systems (environmental management supervisory system)
SEM	scanning electron microscopy
SIS	superconductor-insulator-superconductor
SMC	Sierra Monitor Corp. (combustible gases and oxygen deficiency detector)
SOS	Safety Operations Section (renamed as OSO)
STM	scanning tunneling microscopy
STP	standard temperature and pressure
TLV	threshold limit value
TWA	time-weighted average

UBC	Uniform Building Code
UEL	upper explosive limit
UFC	Uniform Fire Code
UFL	upper flammable limit
ULPA	ultra-low-particulate air (filter)
UPS	uninterruptible power supply
VOC	volatile organic compound

SECTION 1

SCOPE

This document describes the Microdevices Laboratory's (MDL) technical and facility operations, as well as associated safety policies, procedures, and emergency response. Any recommended change in operations, policies, or procedures that affects the contents of this document will be reviewed and approved by the MDL Manager and the Space Microsensors Technology Section (384) Manager prior to implementation. Any such changes in operations, policies, or procedures will be incorporated in this document.

SECTION 2

OVERVIEW

2.1 DESCRIPTION

The Microdevices Laboratory (MDL), JPL's building 302, is a 38,000-square-foot facility which includes cleanrooms for device processing (5,545 square feet), material deposition (4,910 square feet), and conventional laboratories for characterization (5,400 square feet). Above the conventional laboratories are two levels of offices for about 65 people. Additional space houses the facility's mechanical and air handling equipment.

Appendix 1 shows the floor plan for the first floor. The first floor is made up of the H-6 areas and the conventional B-2 laboratory area (see Appendix 2 and definitions of "B-2 Areas" in Sec. 5.10 and "H-6 Areas" in Sec. 5.26).

The cleanrooms, which are housed in the H-6 areas, are arranged in bays (work areas) and chases (for utilities, mechanical pumps, etc.). The cleanrooms are divided into three categories: class 10 (ISO 4), class 100 (ISO 5), and class 100,000 (ISO 8) (Appendix 3). Areas where hazardous materials associated with semiconductor research are used have an H-6 occupancy designation

Only properly trained and authorized personnel may enter the H-6 areas, including bays 153, 143, 147; the hydrogen gas bunker 302-155; the hazardous gas bunker 302-154; and the service areas – such as the recirculation plenum 302-237, the mechanical area 302-236, the service pad, and the cleanroom chases. Authorization procedures and training requirements for access are defined in Section 3.4 and 6.4, respectively. Additional checkouts and training are required to operate equipment (see Sec. 15.2.4).

2.2 TECHNICAL PROCESSING FACILITIES

MDL facilities provide for "end-to-end" fabrication, characterization and rapid prototyping of devices based on silicon, III-V compound semiconductors, amorphous semiconductors, and superconductors with submicron feature sizes.

2.2.1 Material Deposition

- Molecular beam epitaxy (MBE) and in-situ characterization
  - Two III-V growth chambers, one silicon growth chamber
  - In-situ surface characterization (RHEED, XPS, and Auger Spectroscopy)

- Organo-Metallic Vapor Phase Epitaxy (OMVPE) or

- Metallo-Organic Chemical Vapor Deposition (MOCVD)

- Sputtering (Magnetron and Diode)

- E-Beam and Resistive Evaporation
- Electron Cyclotron Resonance (ECR) deposition
- Low Pressure Chemical Vapor Deposition (LPCVD).
- Plasma Enhanced Chemical Vapor Deposition (PECVD).

2.2.2 Lithography

- High resolution electron-beam lithography
- Optical (UV) lithography with both frontside and backside alignment capability.

2.2.3 Device Processing

- Wet etching
- Plasma and Reactive Ion Etching (RIE)
- Ion beam milling
- Chemical Assisted Ion Beam Etching (CAIBE)
- Silicon oxidation and diffusion
- Wire bonding, die separation and die attach equipment
- Deep Trench Reactive Ion Etching (DRIE)
- Rapid Thermal Processing
- Flip Chip Aligning / Bonding
- Fusion / Anodic Bonding

2.2.4 Surface / Interface Characterization

- Scanning Tunneling Microscopy (STM)
- Ballistic Electron Emission Microscopy (BEEM)
- Transmission Electron Microscopy (TEM) (1.8Å point-to-point resolution) with EDAX

- Scanning Electron Microscopy (SEM)
- Atomic Force Microscopy (AFM)
- Electron Spectroscopy for Chemical Analysis (ESCA)
- X-ray Diffraction

2.2.5 Bulk Electrical and Optical Characterization

- Photoluminescence (VIS, IR)
- Fourier Transform Infrared Spectroscopy (FTIR)

•Spectrophotometry

- Electrical characterization:
  - Four point resistivity probe
  - I-V / C-V measurements
  - Hall effect measurements

2.2.6 Thin Film Characterization

- Ellipsometry
- Stylus profilometry
- Optical Microscopy
- Interferometry
- Stress measurements

2.3 SPACE MICROSENSORS TECHNOLOGY R&D FOCUS

2.3.1 MEMS Technology

2.3.2 Nanoscience and Advanced Detector Arrays

2.3.3 Superconducting and Micromagnetic Materials and Devices

2.3.4 Infrared Focal Planes and Photonics Technology

2.3.5 In Situ Exploration Technology

SECTION 3

MDL ADMINISTRATIVE AND BUILDING SAFETY POLICIES

3.1 MDL SAFETY MANAGEMENT RESPONSIBILITIES AND ORGANIZATION

3.1.1 Laboratory Policy on safety states that JPL will comply with all Federal, State, and local laws, statutes, and standards relating to personnel and equipment safety.

3.1.2 JPL policy states that all matters pertaining to conformance with regulatory requirements related to occupational safety will be handled by the JPL Occupational Safety Office (OSO). Environmental compliance will be handled by the JPL Environmental Affairs Office (EAO).

3.1.3 JPL OSO and JPL EAO are responsible for obtaining all applicable permits, including payment of fees.

3.1.4 Section 384 is responsible for managing MDL.

3.1.5 All managerial roles include safety responsibility. The Section 384 Manager has the responsibility for and control over most operations, including the responsibility for the safety aspects of such operations.

3.1.6 The Section Manager in consonance with the JPL EAO is responsible for adherence to environmental laws and regulations governing training, permits, and specific operating conditions.

3.1.7 The Manager of Section 384 is responsible for the safety practices within MDL.

3.1.8 The Section Manager will ensure that:

- Each employee has proper safety education, training, and information.
- Each employee is qualified and motivated to apply safety standards.

3.1.9 The Section Manager is responsible for ensuring that proper record-keeping procedures are followed for equipment and processes under his cognizance.

3.1.10 The MDL Safety Engineer, with Section management and the JPL OSO, is responsible for establishing, implementing, and coordinating all safety practices.

3.1.11 Responsibility for establishment, maintenance, and enforcement of safe working conditions and procedures rests with line management.

3.1.12 Supervisors must ensure that assigned personnel are familiar with all applicable safety regulations and follow procedures outlined in JPL and MDL Safety Manuals (JPL D-2810 and JPL D-6226--this document, respectively).

3.1.13 Supervisory personnel are to:

- Be familiar with the JPL and MDL safety and environmental compliance procedures.
- Ensure that all employees reporting to them are aware of the safety and environmental requirements and have been fully trained.
- Make certain that all operations under their supervision are conducted in accordance with the contents of the JPL and MDL Safety Manuals.

3.1.14 All employees have responsibility for conducting their work in a safe manner.

3.2 MDL SAFETY OVERSIGHT

3.2.1 Due to the concentration of hazardous operations and materials within the confines of the Microdevices Laboratory (MDL), a safety / facilities oversight management structure has been established to aid Section management in local safety / facilities oversight; keep it informed on safety and facilities related issues; make recommendations on what actions should be taken; and aid in the communication interfaces with the JPL OSO, JPL EAO, JPL Occupational Health Services, the JPL Fire Dept., JPL facilities, and outside contractors.

3.2.2 This organizational structure is shown diagrammatically in Fig. 3-1. Its primary management structure consists of the MDL Configuration Control Group. The MDL Configuration Control Group is made up of the MDL Manager, the MDL Safety Engineer, and the MDL Facilities Engineer. Additional staff is provided to effect implementation of needed actions. Experienced and knowledgeable members of the JPL technical staff, the JPL OSO, the JPL EAO, the JPL Occupational Health Office, the JPL Fire Dept., and JPL facilities, as well as outside consultants may be called on to participate on an as-needed basis. (See also Section 7 for a detailed description of configuration control within MDL.)

3.2.3 The MDL Safety Engineer is responsible for MDL Safety oversight and is charged with the following responsibilities:

1. Reviewing all MDL safety and environmental policies and procedures.

2. Ensuring that the MDL is in compliance with all applicable occupational safety and environmental regulations, with an emphasis on practices related to hazardous operations involving acutely hazardous materials (AHMs).

3. Ensuring that all laboratories are properly marked with appropriate safety signs and labels.

4. Conducting MDL Hazardous Operational (Haz-Op) Safety Reviews as often as necessary, recommending procedures for safe operations, and maintaining appropriate records of same.

5. Ensuring all applicable MDL operations have up-to-date JPL Pre-Operational Safety Reviews (Pre-OSRs).

6. Reviewing periodically the inventory of hazardous materials in MDL and tracking chemicals in and waste out.

7. Investigating all unusual safety incidents and recommending corrective measures.

8. Developing emergency procedures within the context of the JPL Hazardous Materials Business Plan and Emergency Preparedness Program.

9. Ensuring that the MDL operations staff, the JPL Fire Department, and the MDL First Floor Wardens are properly trained.

10. Maintaining current MSDSs on chemicals utilized in MDL.

11. Maintaining safety-training records on users of the facility.

12. Interfacing with JPL OSO, JPL EAO, JPL Occupational Health Services, JPL Fire Dept., the MDL Manager, and the Section 384 Manager.

13. Establishing and implementing MDL emergency response procedures.

14. Publishing minutes of applicable safety meetings.

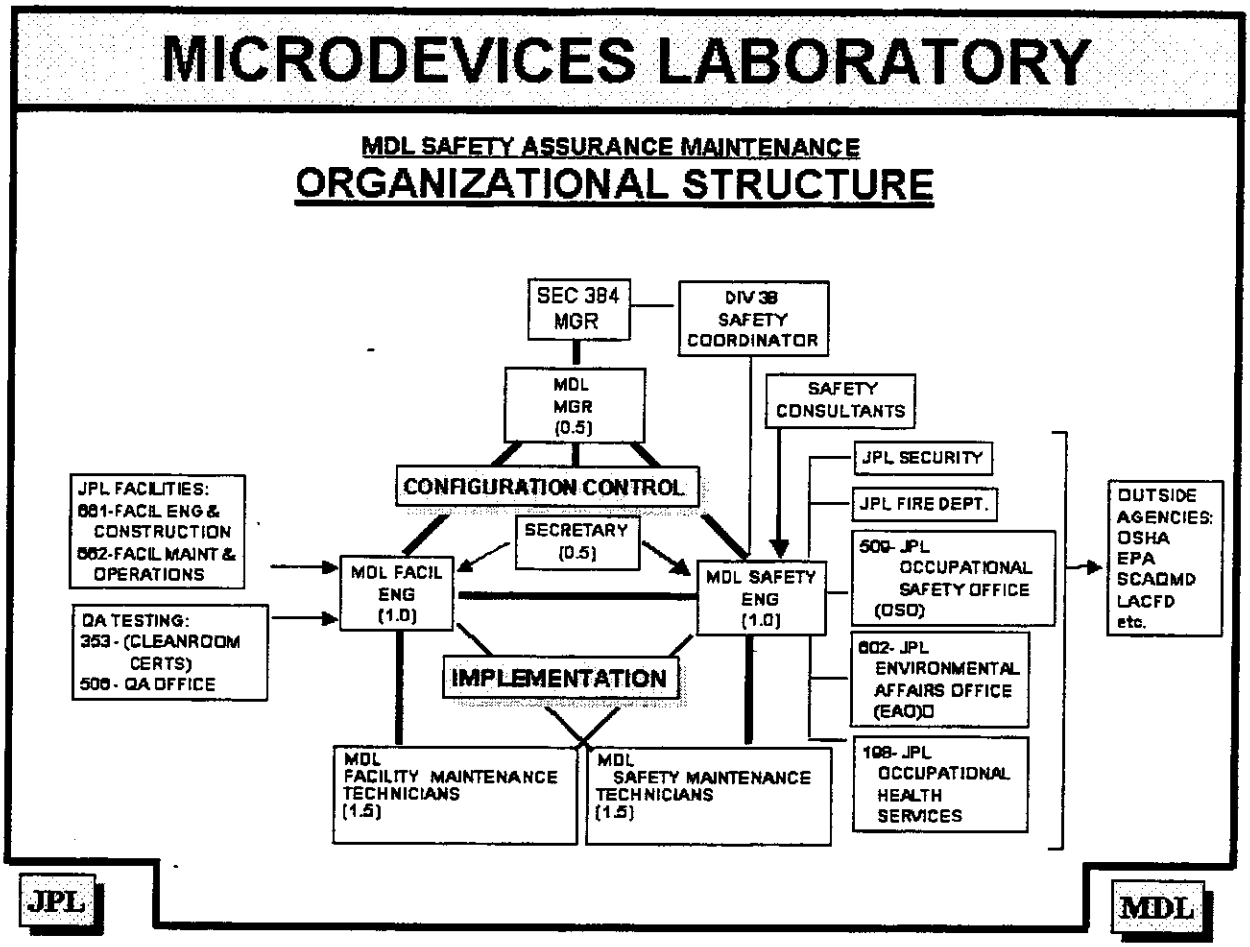


Figure 3-1. MDL Safety Management Organization

3.2.4 Safety is maintained in MDL through the use of the MDL Safety TRIAD. The MDL Safety TRIAD consists of:

1. Separation
2. Monitoring, and
3. Control.

Control may be further subdivided into engineered and administrative controls.

3.3 BUILDING SHIFTS AND HOURS OF OPERATION

3.3.1 Normal hours of operation for MDL are from 6:00 a.m. to 8:00 p.m. Monday through Friday. All other times, including weekends and holidays, are considered off hours.

3.3.2 Personnel engaging in operations that require routine work during off hours will post their operating schedules on the corresponding Pre-Operational Safety Review (Pre-OSR).

3.3.3 Personnel engaging in operations that involve hazardous production materials who are required to work on a non-routine basis during off hours must notify the MDL Safety Engineer prior to performing work.

3.3.4 All hazardous off-hours operations must be performed in groups of two or more (buddy system), or utilize the pendant alarm system.

3.3.5 Hazardous operations are those operations that involve any of the following:

- Maintenance or service of processing equipment that involves high temperatures (over 400 F; 204 C), high voltages (over 120 volts) or high currents (over 30 amps).
- Chemical solutions in quantities exceeding 200 ml, including all acids, asphyxiants*, bases, solvents**, oxidizers, poisons, flammable solids, and pyrophorics.
- Specific acutely hazardous gases (e.g. phosphine, diborane, and arsine).
- Any metallo-organic materials.
- Any work on live circuits over 50 volts.
- Radiation (including lasers with a class 3 or 4 rating).
- Lifting that involves hoists or cranes and loads over 50 lb.
- Machine Shop operations involving major equipment (e.g. lathes, mills, band saw).

*When used in a quantity sufficient to deplete oxygen in the room. Such operations should be defined in their associated Pre-OSR. All areas with plumbed liquid nitrogen are equipped with oxygen deficiency sensors and are continuously monitored; therefore these areas do not require the buddy system for this application.
** Squeeze bottles are exempt.

3.3.6 Smoking is not allowed anywhere in MDL, or within 25 feet of the Hazardous Gas Bunker, Hydrogen Bunker, or flammable gas cylinders.

3.4 ACCESS AND AUTHORIZATION

The main entrance to MDL is through the second level of the building. Stairways at each end of the main corridor provide access to the clean room and laboratory areas on the first level and to the offices on the second and third levels.

Badge readers control all entrances to MDL. During normal working hours, the badge readers will give access to all JPL personnel and contractors with a valid encoded JPL ID badge. During off hours, the badge readers will give access only to personnel directly involved with MDL.

3.4.1 H6 Access and Authorization

Access to the H-6 areas of MDL is controlled by a badge reader and is considered a restricted area. An MDL users list is submitted to the Plant Protection Section for approval and addition to the badge reader data base. MDL users who have completed the required annual MDL safety training program as described in Section 6.4 of this manual will be given access to these areas as authorized by the MDL Manager or designated alternate.

3.4.2 Visitors and Contractors

3.4.2.1 Visitors and contractors who will not enter the H-6 areas must be instructed on evacuation procedures. This may be performed by the MDL Safety Engineer or the person being visited if that person has completed all training requirements. (See Appendix 19.)

3.4.2.2 Visitors and contractors who will enter the H-6/cleanroom areas must have a memo generated by the visitor's contact requesting temporary escorted H-6 access. This memo must be signed by the cognizant group supervisor and the MDL Manager. The visitor will then go through a safety and clean room procedures briefing by the MDL Safety Engineer, the MDL Manager, or their designated alternates, prior to being given access authorization. (See Appendix 19 and Section 15 for details.) The memo must identify the visitor, his or her affiliation, the reason for entry or nature of work to be done, the specific area to be visited, and the person or persons who will act as an escort. (See example memo in Appendix 4.)

3.4.2.3 Visitors or contractors who will perform work in the H-6 clean room area but will not perform hazardous operations will go through the same procedure as escorted visitors outlined in Sec. 3.4.2.2. The safety and clean room training will be more detailed. The example memo in Appendix 4 may be used.

3.4.3 Students and Non-Section 384 Personnel

Students and non-Section 384 personnel who will enter or perform work in the H-6 areas must fill out the MDL Authorization Form (Appendix 5) prior to receiving the annual safety training and test. In addition, all new processors will be assigned a qualified clean room contact (mentor) by the cognizant group supervisor, who will be responsible for ensuring that all MDL policies and procedures are followed. (See also Sections 15.1.1.1 through 15.1.1.4.)

3.4.4 Hazardous Materials Operations

All personnel who will work with hazardous materials or processes in the H-6 areas must annually compete an MDL Authorization Form (Appendix 5). This form must be approved by both the individual's immediate supervision and the MDL Manager prior to beginning operations. The MDL Safety Engineer will keep the original form in the employee's file. The person will receive the full annual safety training. This includes a test, which must be passed with a score of 85% or better. Annual medical monitoring will be performed on these personnel for hazardous chemicals with which they work as reviewed and approved by the JPL OSO. (See Section 3.8.)

3.4.5 After-Hours Access

All after hours MDL work requires authorization. After hours access may be requested by the cognizant group supervisor initially on the MDL Authorization form if their work requires it. Personnel not initially authorized are required to contact the MDL Safety Engineer, the MDL Manager, or one of their designated alternates during regular working hours for authorization to perform after-hours work. A list of off-hours authorized users is posted at the entrance to the H-6 area. Prior to entering the clean room during off hours, personnel on this list are required to contact JPL Security at 4-3530, give their employee number, location and duration of work to be performed, and sign in on the after-hours clipboard posted at the H-6 entry door. When leaving the clean room, personnel must contact the JPL Security console at 4-3530, inform the console operator that work has been completed, and sign out on the after hours clipboard.

3.5 BUDDY SYSTEM

3.5.1 The buddy system is defined as the practice of having two persons within contact of each other at all times, or utilization of the electronic pendant alarm system.

3.5.2 All hazardous gas bunker operations must be performed using the buddy system. The only exceptions to this are hydrogen cylinder changes and status inspections.

3.5.3 All hazardous off-hour operations must be performed using the buddy system.

Hazardous operations are those operations that involve any of the following:

- Maintenance or service of processing equipment that involves temperatures (over 400 F, 204 C), high voltages (over 120 volts) or high currents (over 30 amps).
- Chemical solutions in excess of 200 ml. including all acids, asphyxiants*, bases, solvents**, oxidizers, poisons, flammable solids, and pyrophorics.
- Specific acutely hazardous gases (e.g. phosphine, diborane, and arsine).

- Any metallo-organic materials
- Any work on live circuits over 50 volts.
- Radiation (including lasers with a class 3 or 4 rating).
- Lifting that involves hoists or cranes and loads over 50 lb.
- Machine shop operations involving major equipment (e.g. lathes, mills, band saw).

* When used in a quantity sufficient to deplete oxygen in the room. Such operations should be defined in their associated Pre-OSR. All areas with plumbed liquid nitrogen are equipped with oxygen deficiency sensors and are continuously monitored; therefore these areas do not require the buddy system for this application.
** Squeeze bottles are exempt.

3.6 CHANGES, MODIFICATIONS, ADDITIONS, AND DELETIONS

3.6.1 Any change or modification performed on any equipment, operation, or procedure that affects the operational description in the Pre-OSR must be submitted in writing to the MDL Safety Engineer for approval prior to implementation. In most cases, a new Pre-OSR will have to be filled out and approved by the JPL OSO, JPL EAO, and the MDL Configuration Control Group prior to implementing the change or modification.

3.6.2 All changes, modifications, addition, or deletions to any operation, equipment, utilities, or structure must go through Configuration Control as described in Section 7 of this manual. Also see Section 8 (Facilities) of this manual.

3.6.3 Any changes, modifications, or addition of systems involving acutely hazardous materials, in addition to Configuration Control, must go through a hazard and operability (HAZ-OP) study as described in Section 7.3 of this manual.

3.7 DISCIPLINARY ACTIONS

All MDL users are responsible for understanding and complying with all JPL policies and procedures at all times while working in MDL. These policies are defined in the JPL DMIE system found at http://dmie.jpl.nasa.gov. Specific policies are defined in this MDL Safety Manual: Operations, Policies, and Procedures Plan and the JPL Safety Manual and are fully explained in the training courses given prior to beginning employment and during the annual Section (384 & MDL) Safety Training.

Disciplinary actions will be in correspondence with the JPL Disciplinary Policy Document # 11004. Discipline is intended to provide notice to an employee that the employee's performance or conduct does not conform to expectations. With some exceptions, discipline is progressive and is administered in stages up to and including discharge for cause. When situations arise which call for discipline more severe than a discussion or an oral warning, the laboratory reserves the right to modify or to accelerate a corrective action at any stage of discipline including immediate

termination. Often, safety offenses can fall into this category of accelerated discipline, depending on the severity of the offense.

3.7.1 Stages of Disciplinary Action

- Stage 1. Discussion.
- Stage 2. Oral Warning (Step 1).
- Stage 3. First Written Warning (Step 2).
- Stage 4. Final Written Warning (Step 3).
- Stage 5. Involuntary Release (Step 4).

The stage at which discipline is initiated will depend on the severity of the problem.

3.7.2 Suppressing Information

Any attempt by the concerned individual to suppress disclosure or investigation of the incident automatically amplifies its seriousness.

3.7.3 Reporting of Violations

It is the responsibility of all personnel to educate, coach and mentor their fellow workers if they note violations of JPL / MDL policies or procedures. If the practices persist, personnel have a responsibility to report violations to line management. MDL policy violations should be reported to the MDL Manager or designated alternate. If a safety violation occurs within MDL, the details and circumstances of the violation (reference Sec. 16.5, "Accident Investigation") should be reported to the MDL Safety Engineer, the MDL Manager, and the Cognizant Supervisor. They shall ensure that said information is conveyed in a timely manner to Section Management. Depending on the severity of the violation, details and circumstances will be reported to Division Management, the Division Safety Coordinator, and elsewhere, as required. If applicable, the Mishaps Report Form (JPL # 0554 S) (reference Sec. 4.16) should be filled out.

3.7.4 Initiation of Disciplinary Action

A prompt solution to problems through informal discussion and counseling with the employee should be attempted by the cognizant supervisor. If further actions are required, formal disciplinary actions (Stage 2 and above) are initiated by an employee's immediate supervision in concert with the next level of line management and Employee Relations.

3.7.5 Contractor-Involved Violations

If a contractor employee is involved in a violation (especially a safety violation), and informal counseling is insufficient to correct the situation or conduct, the Cognizant Supervisor in concert with Section Management shall notify the contractor employee's

supervisor, advising him or her of the severity of the violation. Discipline of contractor personnel is to be handled by the contractor company's management.

3.8 MEDICAL AND PHYSICAL EXAMINATIONS

3.8.1 Medical Examinations

3.8.1.1 Medical examinations performed for reasons of monitoring for exposure or effects of hazardous environments or materials/physical agents at JPL will be coordinated through JPL Occupational Health Services.

3.8.1.2 Supervision in conjunction with the JPL OSO determines the need and frequency required for medical examinations on all personnel who are exposed to or work with hazardous chemicals. Such examinations are mandatory for personnel who will normally access the H-6 area of MDL (bldg. 302) as part of their job assignment and are typically done on an annual basis. New personnel who are expected to work with or near hazardous chemicals shall undergo a physical examination within three months of their start date to establish a medical surveillance program to use as a baseline reference for subsequent annual examinations.

3.8.1.3 Medical Surveillance (i.e. medical examination) requests are initiated by the cognizant group supervisor, by filing out a Medical Surveillance Request Form (JPL #2633-S) (see Section 4.20). These forms are submitted to JPL OSO who reviews and approves them, although it is recommended that the forms be submitted first to the MDL Safety Engineer for review and comment. If approved by JPL OSO, they are forwarded to JPL Occupational Health Services who will schedule and coordinate the required medical reviews and examinations.

3.8.1.4 MDL personnel are given a grace period of three months after their annual deadline to complete all medical requirements. If these requirements are not met, personnel may not be allowed to do any further work in hazardous environments or involving hazardous materials at the discretion of MDL Management.

3.8.1.5 All medical examination records will be kept on file by JPL Occupational Health Services. These records are considered DISCREET.

3.8.2 Laser Eye Examinations

A special ophthalmologic examination shall be performed whenever an exposure occurs and an eye injury is suspected. Personnel who work with lasers may request additional eye examinations. As required by JPL OSO and JPL Occupational Health Services.

3.8.3 Lung and Respiratory Examinations

Personnel who work in particulate dust, mist, aerosol, fume, or vapor-generating environments that require respiratory protection shall undergo annual spirometry or lung

capacity tests if deemed necessary by the JPL Occupational Health Services and JPL Occupational Safety Office. Further training to allow the use of respirators or other PPE is also required. Such training must be periodically renewed (See JPL Safety manual).

3.9 TRAINING POLICY

Only properly trained and authorized personnel may enter the H-6 and clean room areas, including bays 143, 147, and 153; the hydrogen gas bunker 302-155, the hazardous gas bunker 302-154, and the service areas – such as the re-circulation plenum 302-237, the mechanical area 302-236, the service pad, and the clean room chases. Section 6.4 specifies the required training for such personnel. Current records of training attendance rosters, dates, and, if applicable, test scores, will be kept on file in the MDL Safety Engineer's office. The records are to be kept for 30 years.

Additional checkouts and training are required to operate equipment within the H-6 area. (See Section 15.2.4 for details.) These records are either stored in equipment logbooks or electronically at the http://mdlwww website by the Cognizant Engineer or designated alternates (e.g. designated trainers) and will be kept until the relevant piece of equipment is retired. Authorization / training will remain in effect for two years after active use of the equipment, although the qualification status may be challenged and terminated at any time by the Cognizant Engineer.

SECTION 4

DOCUMENTS, LOGS AND FORMS

4.1 AFTER-HOURS AUTHORIZATION LIST

Personnel on this list have authorized after-hours (24 hour) access into the MDL H-6 areas. Prior to entering the H-6 areas, cleanroom personnel on this list are required to contact JPL Security at 4-3530 and give their employee number, location, and duration of work to be performed. When leaving the cleanroom, personnel shall contact JPL Security at 4-3530 and inform them that work has been completed.

Personnel not on this list who need to work in the H-6 area after regular working hours, are required to contact the MDL Safety Engineer, the MDL Manager or designated alternate during regular working hours for after-hours access authorization.

Requests for personnel additions to the after-hours (24 hour) MDL H-6 Area Access List are made by requesting this access from the MDL Manager who authorizes the addition. These requests may be made through the "MDL Authorization Form" (See Appendix 5), or by a separate memo. Relevant supervisor concurrence is required.

This list has been incorporated into the "MDL H-6 Area Access List" (See Sec. 4.15.) A dated reference copy of the "MDL H-6 Area Access List" which lists all H-6 authorized users and indicates those with after-hours (24 hour) authorization is posted by the H-6 entry in the controlled lighted bulletin board. The custodian for the listing is the MDL Safety Engineer who maintains the list electronically and provides the list and updates to JPL Security.

4.2 AFTER-HOURS SIGN-IN LOG

This log is posted at the main entrance to the MDL H-6 area. Personnel must sign in and out on this log whenever entering the MDL H-6 areas before 6:00 a.m. or after 8:00 p.m. on weekdays, or any time on weekends or holidays (i.e. for after hours work).

4.3 CHEMICAL INVENTORY FORMS

Chemical inventory forms are required on all cabinets and work areas where chemicals are stored. This form lists the maximum quantity of chemicals that may be found at the work area or cabinet. If additional or larger quantities of chemicals are needed, contact the MDL Safety Engineer or an MDL Safety Technician.

4.4 CLEANROOM ACCESS LIST

This list indicates all personnel authorized to enter the cleanroom (Class 100-10, ISO 5-4) envelope. It is maintained electronically within the cardreader database at the entrance to the air shower. Additions to the database may be inputted by members of

the Central Processing and MDL Support Group on verification that all requirements for access have been met. (See also "4.15 MDL H-6 Area Access List".)

4.5 CLEANROOM SIGN-IN LOG

This log is located by the shoe cleaner at the entrance to the cleanroom gowning area (302-141). Personnel are responsible for signing in and out on this log whenever entering and exiting the MDL cleanrooms. An alternate electronic log-in/log-out system utilizing a badge reader has been installed and may supersede this log.

4.6 EMERGENCY SHUTDOWN PROCEDURE (ESP)

This form is required only for equipment and operations that may be damaged if shut down inappropriately. It is required if such an operation is left in an unattended powered condition. It is the responsibility of the cognizant engineer to prepare this form. The form should contain the minimum steps to quickly power down the instrument in a controlled safe manner and a diagram or illustration that shows the relative locations of the pertinent controls. It should be noted that, depending on the nature of the emergency, immediate equipment and building power shutdown may be unavoidable.

4.7 EQUIPMENT OPERATING SIGNS

Equipment operating signs are available through JPL General Supplies or the MDL Safety Support Team. The cognizant engineer is required to prepare and post such a sign on each instrument left in an unattended powered condition.

4.8 EQUIPMENT OPERATIONS LOGS

Equipment Operations Logs are specific to each piece of processing equipment. These logs list the cognizant engineer and all personnel trained and authorized to use the equipment, operating procedures, maintenance modifications and repairs to the equipment, and parameters specific to each process run. Specific authorization and training are required to operate equipment within MDL. Some or all of this data may be stored electronically.

4.9 FACILITIES SERVICE REQUEST FORM

The hardcopy version of this form (JPL # 0313-S R 01/99) has been retired since the primary method of making service requests is electronically through the link located on the timekeeping website. This form is also available on-line through JPL electronic forms. Note that all FSRs for work in MDL must be routed through the MDL Facilities Engineer. (See Sections 7 and 8.)

4.10 HAZARDOUS WASTE DISPOSAL FORM (JPL # 2799-S)

A Hazardous Waste Disposal Form is required by JPL Environmental Affairs Office (EAO) for the disposal of hazardous materials. Forms for waste generated in the cleanroom areas in MDL are filled out by the MDL Safety Technician or the MDL Safety Engineer or designated alternates. (Hazardous waste labels filled out by the users (see Sec. 6.2) are used in completing this form.) Forms for waste generated outside of the cleanrooms or in buildings other than MDL will be generated by the cognizant engineer. These forms are available through JPL Electronic Forms or JPL EAO. A unique number and bar coding must be assigned to each. A sample form may be viewed in Appendix 6.

4.11 MAINTENANCE AND FACILITIES SIGN-IN LOGS

These logs are located just outside room 302-222, on the second floor in the mechanical area (302-236) and on the first floor in the equipment pad area. Facilities, maintenance, and outside contractor personnel who are doing service work or inspections must sign in and out on one of these logs when entering and leaving MDL and the relevant areas. Personnel who have not signed out during an evacuation are accounted for at assembly areas. The JPL Fire Department will conduct a search and rescue effort for anyone unaccounted for at the assembly areas.

4.12 MATERIAL SAFETY DATA SHEETS (MSDS)

Additional information on MSDSs is contained in Section 6.3 of this document.

Personnel performing work involving hazardous materials are responsible for reading and understanding the MSDS for each hazardous material that they work with. Any questions on the information contained in the MSDS should be posed to the MDL Safety Engineer or the JPL OSO.

4.12.1 Location and Availability

Material Safety Data Sheets are located in the MDL Lobby (302-200), just outside of the MDL Library (302-211); the JPL Occupational Health Services Office; the JPL Fire Department; and the JPL Occupational Safety Office. MSDSs are available for reviewing or copying to anyone from the MDL Lobby location (302-200) or upon request to the MDL Safety Engineer or the MDL Safety Technicians.

4.12.2 Description of Typical MSDS Sections

Section 1 - Manufacturer's Information:
- Manufacturer's name
- Manufacturer's address
- Emergency phone numbers

Section 2 - Hazardous Ingredients Identity and Exposure Limits:
- Product name

- Trade name and synonyms
- Chemical family
- Formula/chemical structure
- Hazardous ingredients
- Permissible Exposure Limit (PEL) and Threshold Limit Value (TLV) information

Section 3 - Physical Data:
- Molecular weight
- Boiling point/freezing point
- Vapor density/pressure
- Percent volatility
- Solubility in water -
- Specific gravity
- State at STP
- Appearance
- Odor

Section 4 - Fire and Explosion and Hazard Data:
- Flash point
- Explosive/flammability limits
- Extinguishing media
- Special fire-fighting procedures
- Fire-fighting protective clothing
- Unusual fire and explosion hazards (e.g. decomposition, emission of toxins etc.)

Section 5 - Health Hazard Information:
- Exposure limits (e.g. TLV, etc. information)
- Effects of overexposure
- First aid procedures/eye, skin, inhalation, ingestion

Section 6 - Reactivity Data:
- Stability
- Incompatibilities
- Hazardous decomposition products
- Hazardous polymerization

Section 7 - Spill or Leak Procedures:
- Steps to be taken in case material is released or spilled
- Waste disposal methods

Section 8 - Special Protection:
- Personal protective equipment
- Ventilation

Section 9 - Other special precautions
Section 10 - Transportation data

4.12.3 User Responsibility

a. Notification of new chemicals to the MDL Safety Engineer.
b. Familiarization with MSDS information for all hazardous materials used or exposed to.

4.12.4 MDL Safety Engineer's MSDS Responsibility

a. Acquire current MSDSs of all hazardous chemicals used within the section.
b. Maintain complete listing of MSDSs and make available to all users.

4.13 MDL AUTHORIZATION FORM FOR NON-SECTION 346 PERSONNEL (Retired 4/13/99) This form has been retired and the function merged with an authorization form for ALL personnel who will enter or perform work within the laboratory areas of MDL. See Section 4.14 and Appendix 5.

4.14 MDL AUTHORIZATION FORM (MDL # 41399)

All personnel who will enter or perform work within the laboratory areas of MDL must fill out the MDL Authorization Form (Appendix 5). This form documents authorizations from the individual's immediate supervision and MDL management, provides a means for requesting after-hours access, and defines anticipated user categories and account numbers for MDL user fees. In addition, all new processors will be assigned a qualified cleanroom contact (mentor) by the cognizant MDL group supervisor. (MDL group supervisors consist of any technical group supervisor at JPL who has personnel accessing the MDL H-6 area and who is familiar with the MDL Safety Policies and Practices as demonstrated by taking the Section (384 & MDL) Annual Safety Training and who is willing to take responsibility and provide active oversight for employees within MDL. The status is bestowed by the MDL Manager.) The mentor is responsible for ensuring that all MDL policies and procedures are followed and the mentor is identified on this form. (See also Section 3.4.) The form is renewed annually at the time the annual Section (384 & MDL) Safety Training is taken and stored with the employees records by the MDL Safety Engineer. A certification record is included with each form.

4.15 MDL H-6 AREA ACCESS LIST

Personnel on this list have authorized access into the MDL H-6 areas. The "After-Hours Authorization List" (See Sec. 4.1) which indicates H-6 authorized personnel with after-hours (24 hour) authorization, has been incorporated into the "MDL H-6 Area Access List". A dated reference copy of the "MDL H-6 Area Access List" is posted by the H-6 entry in the controlled lighted bulletin board. The custodian for the listing is the MDL Safety Engineer who maintains the list electronically, periodically posts a hardcopy at the H-6 entrance, and provides the list and updates to JPL Security.

4.16 MISHAP REPORTS FORM (JPL 0554 S)

This new JPL form replaces Unusual Incident Reports, JPL Form 1373-S, and Contractor and Employee Injury Reports, JPL forms 0544-S and 0544-1-S, respectively. Hardcopy forms may be obtained from the JPL Occupational Safety Office. The Section Safety Coordinator / MDL safety Engineer should be contacted for an appropriate ID number.

A Mishap Report must be filled out any time an event occurs due to the unforeseen and/or improper functioning of a component, system, or process that results in one or more of the following:

- A safety hazard.
- Injury to personnel.
- Damage amounting to $1,000 or more to a facility or its equipment.
- Close calls.

A Mishap Report must be filled out for all work-related injuries by the injured person or his Group Supervisor and must be approved by the Section Manager. (See also Sec. 16.5.)

4.17 PRE - OPERATIONAL SAFETY REVIEW (OSR, JPL # 0284)

Pre-OSRs are required for all operations that involve the following:

- Chemicals, including all acids, asphyxiants, bases, solvents*, oxidizers, poisons, pyrophorics, flammable solids, explosives, carcinogens, teratogens, mutagens, and reactive materials.
- High temperatures (over 400 F; 204 C).
- High voltage (over 600 volts).
- Any work on live circuits over 50 volts.
- Radiation (including lasers with a class 3 or 4 rating).
- Lifting that involves hoists or cranes and loads over 50 lb.
- Hazardous gases.

- Squeeze bottles (1000 ml or less) or acetone, isopropyl alcohol, or methanol are exempt.

Pre-OSRs shall be reviewed annually or when any significant change in the operation is made. Ongoing operations are given a 3-month grace period. After this grace period, if a new Pre-OSR is not submitted, the operation may be shut down. New operations may not begin to operate until a Pre-OSR has been submitted and approved. Pre-OSRs must be posted in a conspicuous location on the equipment or at the operation location.

4.18 MDL SAFETY MAINTENANCE PLAN AND SERVICE MANUAL (JPL D-6542)

The MDL Safety Maintenance Plan and Service Manual contains a description of all life safety systems in MDL, along with model and JPL ID numbers, maintenance schedules and information, and manufacturer contacts and telephone numbers. This manual has been prepared to ensure the proper and continuous maintenance and operation of the MDL life safety systems. Additional information may be available and kept by the MDL Safety Engineer.

4.19 MDL FACILITIES MAINTENANCE PLAN (JPL D-6707)

The MDL Facilities Maintenance Plan contains a description of facilities systems in MDL, along with model and JPL ID numbers, maintenance schedules and information, and manufacturer contacts and telephone numbers. This manual has been prepared to ensure the proper and continuous maintenance and operation of the MDL facilities systems. Additional information may be available and kept by the MDL Facilities Engineer and the MDL Safety Engineer.

4.20 MEDICAL SURVEILLANCE REQUEST FORM (JPL 2633-S)

The "Medical Surveillance Request Form (JPL 2633-S)" is required to initiate a physical examination. These forms are available from JPL electronic forms. This form must be submitted to the Section Safety Coordinator and should be updated and submitted whenever a significant change in work involving hazardous production materials occurs. Potential exposures (i.e. chemicals worked with and frequency of the contact situations) are indicated on the form which will be submitted to the JPL Occupational Safety Office who will evaluate the information to see if medical surveillance and / or a physical examination will be required. (See Sec. 3.8.)

4.21 REQUEST FOR DIRECT USE OF MACHINE SHOP EQUIPMENT AS AN AUTHORIZED MDL USER FORM (MDL #1736 R 1/01)

The "Request for Use of MDL Machine Shop Form (MDL #1736 R 5/00)" has been revised and retitled "Request for Direct Use of Machine Shop Equipment as an Authorized MDL User Form (MDL #1736 R 1/01)". This form must be completed for personnel prior to using major machine shop equipment within the bldg. 103 Tech Shop run by Sec. 357, if they desire to do so under the financial umbrella of an authorized Microdevices Laboratory (MDL) User. (i.e. the hourly charge is paid as a benefit of the MDL User fee.) It documents authorization for use from immediate supervision, cognizant Section Managers (responsible for safety) and provides for a means of safety oversight and skill review prior to use. The form also documents an approval sign-off to obtain a key to the tech shop area for after hours access and use. [Buddy System required.] (See Sec 14.3.1 and Appendix 18.) The MDL Machine Shop Coordinator / Cognizant Engineer will be the custodian of these records.

4.22 JPL CHEMICAL HYGIENE PLAN (CHP)

A JPL Chemical Hygiene Plan (CHP) is required for all laboratories at JPL which conduct chemical operations. It consolidates in a single location relevant information concerning the facility and operations. The CHP for MDL is located with the MSDSs in the MDL Lobby (302-200), just outside of the MDL Library (302-211). A copy resides at the JPL Occupational Safety Office (OSO).

SECTION 5

TERMINOLOGY

5.1 Acid One of a large class of chemical substances whose water solutions have one or more of the following properties:

- Sour taste.
- Ability to turn litmus paper red.
- Ability to react with and dissolve certain metals to form salts.
- Ability to react with bases or alkalies to form salts.

All acids contain hydrogen. In water, ionization or splitting of the molecule occurs so that some or most of this hydrogen forms H_3O^+ ions (hydronium ions), usually written as H^+.

Acids are referred to as strong or weak according to the concentration of the H^+ ion that results from ionization. A pH below 7 indicates acidity. The pH scale is logarithmic. Acids with a pH = 1 (such as tenth normal hydrochloric acid) are 100 times more acidic than acids with a pH = 3 (such as tenth normal acetic acid).

Like bases and alkalis, in sufficient amounts these materials burn, irritate, or destructively attack organic tissues such as the skin, lungs, and stomach.

5.2 Acute exposure a single, short-term exposure.

5.3 Acutely hazardous material (AHM) Any extremely hazardous substance on the list prepared by the Environmental Protection Agency and any supplemental amendments to the list. This list is reviewed and modified on a yearly basis.

5.4 Aerosols Fine suspensions of liquids or particulates in air.

5.5 Agents that act on blood Substances that decrease the hemoglobin function and deprive the body tissues of oxygen. Cyanosis (bluish or purplish skin discoloration) and loss of consciousness are typical symptoms. (Examples: carbon monoxide, cyanides, metal carbonyls, nitrobenzene, arsine)

5.6 Alkali any substance which in water solution is bitter, more or less irritating, or caustic to the skin and mucous membranes; turns litmus paper blue, and has a pH value greater then 7.0.

5.7 Asphyxiant A gas which has little or no toxic effect but which can bring about unconsciousness and death by replacing air and thus depriving an organism of oxygen. (examples: nitrogen, helium, carbon dioxide, methane).

5.8 Autoignition Temperature (AT) The temperature at which a gas or vapor can explode or burst into flames with no other source of ignition.

5.9 Base Corrosive materials whose water solutions contain hydroxyl ions (-OH). Like acids, in sufficient amounts these materials burn, irritate, or destructively attack organic tissues such as the skin, lungs, and stomach.

5.10 B-2 Areas A Uniform Building Code designation for occupancies that are drinking and dining establishments having an occupant load of fewer than 50, wholesale and retail stores, office buildings, printing plants, municipal police and fire stations, factories and workshops using materials not highly flammable or combustible, storage and sales rooms for combustible goods, paint stores without bulk handling, or buildings or portions of buildings having rooms used for educational purposes beyond the 12th grade with fewer than 50 occupants in any room. [Note that MDL, JPL bldg. 302, was designed under 1984 UFC and UBC code requirements and brought into operation and compliance with 1988 UFC and UBC code requirements.]

5.11 Carcinogen Any substance that has the potential of causing the development of cancerous (neoplastic) growths in living tissue. The California Safe Drinking Water and Toxic Enforcement Act of 1986 requires that the Governor revise and republish at least once per year the list of chemicals known to the State of California to cause cancer or reproductive toxicity. This list is available from the MDL Safety Engineer.

5.12 Caustic Any strongly alkaline material that has a corrosive or irritating effect on living tissue.

5.13 Chronic exposure Long-duration, repeated, or prolonged exposure.

5.14 Combustible material Any substance (i.e., solid, liquid, or gas) that will burn regardless of its autoignition temperature (i.e., it includes all flammable materials). This term is disregarded in official documents. Examples of combustible but not flammable materials are sugar and cellulose.

5.14.1 Combustible liquid A liquid with a flash point between 100 F (38 C) and 200 F (93 C).
5.14.2 Combustible solid Solid material which is relatively difficult to ignite and burns relatively slowly.

5.15 Compressed Gas Any substance which, when enclosed in a container, gives a pressure reading of at least:

- 25 psig (pounds per square inch, gauge pressure) at 70 F, or
- Over 89 psig at 130 F, or
- Over 25 psig at 100 F for flammable materials.

5.16 Corrosive substance Any solid, liquid, or gaseous substance burns, irritates, or destructively attacks organic tissues, most notably the skin, or when taken internally, the lungs and stomach. May also dissolve metal, concrete, and other materials.

5.17 Cryogen A material that exhibits specific behaviors at temperatures below -200 C. (e.g., liquid nitrogen, liquid oxygen, liquid helium).

5.18 Cutaneous agent A material that will affect the dermal layer of the body such as by defatting of the skin, causing rashes or skin irritation (e.g., MEK, acetone, chlorinated compounds).

5.19 Explosive Range (ER) The range of concentration of a flammable gas or vapor (% by volume in air) in which explosion can occur upon ignition in a confined area. Example: The ER of hydrogen is 4.1% to 74.2%. The smaller number is referred to as the Lower Explosive Limit (LEL). The larger number is the Upper Explosive Limit (UEL).

5.20 Explosive substances Solid, liquid, or gaseous substances, alone or mixed with one another, that are in a metastable state and capable of undergoing a rapid chemical reaction without the participation of external reactants such as atmospheric oxygen. The reaction can be initiated by mechanical means (e.g., impact, friction), by heat (e.g., sparks, open flame, or red-hot areas), or by detonating shock. The ease with which the chemical reaction can be initiated is known as sensitivity. The detonation byproducts are predominantly gaseous. The propagation rate can be subsonic (gunpowder) or supersonic. Some materials intended primarily for industrial purposes may also be explosive, such as organic peroxides and certain kinds of insecticides. Appendix 7 lists various explosive-forming organic peroxides. Appendix 8 gives a synoptic view over the whole field of explosive materials.

5.21 Eye Hazard A material that affects the eye or visual capacity by causing conjunctivitis (pink eye), retinal damage as from laser radiation, corneal damage or physical damage such as small particulates.

5.22 Flammable aerosol Refers to aerosol emissions that ignite with a flame projection of more than 18 inches or a flame that extends back to an emitting valve.

5.23 Flammable material any solid, liquid, or gas that will ignite easily and burn rapidly.

5.23.1 Flammable liquid A liquid with a flash point below 100 F (38 C) or vapor pressure < 40 psia at 100 F.

5.23.2 Flammable gas A gas with a lower explosive limit (LEL) or lower flash limit (LFL) < 13%; a gas with an upper flash limit (UFL) or upper explosive limit (UEL) > 12% past the LEL or UFL. Flammable gases will ignite very easily.

5.23.3 Flammable solid A solid other than a blasting agent or explosive which burns or ignites easily through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a serious hazard. Solid matter that can sustain a 0.1-in/s flame spread along its major axis, with ignition below 212 C. Dust in air may be ignited or cause an explosion.

5.24 Flash point (FP) The temperature at which a liquid or volatile solid gives off vapor sufficient to form an ignitable mixture with air near the surface of the liquid or within the test vessel.

5.25 Halogenated compounds Any of the class of compounds with component elements from the group VII A of the periodic table consisting of fluorine, chlorine, bromine, iodine, and astatine. Halogens exist in the free state normally as diatomic molecules. (See also Section 9.5.2.1.)

5.26 H-6 Areas As defined in the Uniform Building Code (UBC), a Group H division 6 occupancy applies to semiconductor fabrication facilities and comparable research and development areas in which hazardous production materials (HPMs) are used and the aggregate quantities of such materials are in excess of those listed in Table 51.105A (Appendix 9) or 51.106B (Appendix 10) of the UBC. Such facilities and areas shall be designed and constructed in accordance with Section 911 of the UBC. [Note that MDL, JPL bldg. 302, was designed under 1984 UFC and UBC code requirements and brought into operation and compliance with 1988 UFC and UBC code requirements.]

5.27 Hazardous Production material (HPM) A solid, liquid, or gas that has a degree-of-hazard rating in health, flammability, or reactivity of Class 3 or 4 as ranked by Uniform Fire Code Standard No. 79-3 and which is used directly in research, laboratory, or production processes which have as their end product materials which are not hazardous.

5.28 Health Hazard A general term including irritants, cutaneous hazards, toxic agents, corrosives, eye hazards, agents that act on the blood, sensitizers, carcinogens, teratogens, mutagens, agents that damage the lungs, kidneys, or liver, and neurotoxins. It refers to a chemical or radiation for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees.

5.29 HMRT (Hazardous Materials Response Team) Manned by JPL Fire Department hazardous materials specialists for response to real or potential chemical emergencies.

5.30 IDLH Immediately Dangerous to Life and Health: a level defined by the Standards Completion Project (SCP) (a joint effort by NIOSH and OSHA to develop a series of emergency exposure standards) only for the purpose of respirator selection. It represents a maximum airborne concentration of a chemical from which, in the event of respirator failure, one could escape within 30 minutes without experiencing any escape-impairing or irreversible health effects. Unlike the TLV/PEL and STEL values, it is not a "safe" level of exposure.

5.31 Irritant A chemical which is not a corrosive, but which causes a reversible inflammation at the site of contact by chemical action. It is characterized using albino rabbits. (Examples: nitric oxide, sodium hypochlorite, ethyl alcohol).

5.32 LC 50 Median lethal concentration. That quantity of a substance administered by inhalation that is necessary to kill 50 percent of test animals exposed to it within a specified time. The test applies to gases, fumes, vapors, dust, aerosols, and other particulates suspended in air. Normally used in lieu of the LD50 test in aquatic toxicology and inhalation toxicology.

5.33 LD 50 Median lethal dose. That quantity of a substance administered orally that is necessary to kill 50 percent of exposed animals in a laboratory within a specified time. A substance having an oral LD 50 of less than 400 mg/kg of body weight is considered to be highly toxic.

5.34 LEL or LFL Lower Explosive Limit or Lower Flash Limit or Lower Flammability Limit: the lowest concentration of a substance in air in percent by volume at standard temperature and pressure (STP) that is capable of causing an explosion or flash.

5.35 Mutagen Any chemical compound able to induce mutations in deoxyribonucleic acid (DNA) and in living cells. Alkyl mustards, dimethyl sulfate, diethyl sulfate, and ethyl-methane sulfonate comprise a group of so-called alkylating agents reacting with the nitrogen atoms of guanine, a constituent of both RNA and DNA.

5.36 Oxidizer A chemical, other than blasting agent or explosive, that can initiate or promote combustion in other materials, causing fire either of itself or through the release of oxygen or other gases (e.g., oxygen, chlorine, nitric acid, fluorine, hydrogen peroxide). These chemicals can react with organic material or combustible liquids to cause or intensify fires.

5.37 PEL Permissible Exposure Limit: The eight-hour time-weighted average or ceiling concentration of an airborne contaminant above which workers may not be exposed. A few chemicals have a ceiling (instantaneous) concentration above which people should not be exposed. These PELs are identified with a "C". These values have been established by the U.S. OSHA. {Note that these values sometimes differ from recommended Threshold Limit Values (TLVs) established by the American Conference of Governmental Industrial Hygienists (ACGIH) or the Recommended Exposure Limits (RELs) established by the national Institute for Occupational Safety and Health (NIOSH).}

5.38 pH Potential of Hydrogen. pH is a symbol for the logarithm of the reciprocal of the hydrogen ion concentration, expressed in gram atoms per liter, in an aqueous solution. Given by $pH = \log_{10}(1 / [H+])$, where [H+] is the hydrogen-ion concentration. A pH below 7 indicates acidity, and one above 7, alkalinity. pH is a value used to represent the strength of an acid or base. pH values for acids typically range from 1 to 6, with 1 being a very strong acid and 6 being a very weak acid. Neutral materials have a pH of 7, although this is rarely achieved (e.g. pure water is usually very slightly acidic). pH values for bases will typically range from 8 to 13, with 8 being a very weak base and 13 being a very strong base. See also definitions under Acid, Alkali, and Base.

5.39 Physical Hazard A general classification term which, for a chemical, implies that there is scientifically valid evidence that it is a combustible liquid, compressed gas, cryogenic, explosive, flammable gas, flammable liquid, flammable solid, organic peroxide, oxidizer, pyrophoric, unstable (reactive), or water-reactive material.

5.40 Poison (Toxicant) Any substance that is harmful to living tissues when applied in relatively small doses. The most important factors involved in impacting dosages are:

1. Quantity or concentration
2. Duration of exposure
3. Particle size or physical state of the substance
4. Affinity of the substance for living tissue
5. Solubility of the substance in tissue fluids
6. Sensitivity of the issues or organs

Classes:

POISON A. Gas or liquid so toxic that an extremely small amount is dangerous to life.

POISON B. Less toxic liquids or solids that are hazardous either by contact with the body (absorption) or through ingestion.

POISON C. Poisons or toxins that evolve extremely toxic or irritating fumes when heated or exposed to air.

POISON D. Radioactive materials.

5.41 Pyrophoric Material Any liquid or solid that will ignite spontaneously in air at less than or equal to 130 F (54.4 C). Titanium chloride and phosphorus are examples of pyrophoric solids. Trimethylaluminum and trimethylgallium and related compounds are pyrophoric liquids. Sodium is spontaneously flammable in moist air as it reacts exothermally in water. Silane and most hydrides are gaseous pyrophors. Such materials must be stored in an atmosphere of inert gas or under kerosene.

5.42 REL Recommended Exposure Limit: Unless otherwise specified, this refers to the time-weighted average (TWA) concentrations for up to a 10-hour workday during a 40-hour workweek. These values are established by the National Institute for Occupational Safety and Health (NIOSH). (See also PEL and TLV, this section.)

5.43 STEL Short-Term Exposure Limit: The maximum concentration to which a person may be exposed for up to 15 minutes, four times per day, with one hour intervals in between so long as the time-weighted average over an eight-hour day is not exceeded. The STEL is the concentration to which workers can be exposed to continuously for a short period of time without suffering from adverse effects.

5.44 Teratogen An agent that causes growth abnormalities in embryos or genetic modifications in cells (e.g., ionizing radiation).

5.45 TLV Threshold Limit Value: A set of standards established by the American Conference of Governmental Industrial Hygienists for concentrations of airborne

substances in workroom air. They are time-weighted averages based on conditions to which it is believed that workers may be repeatedly exposed day after day without adverse effects. A few chemicals have a ceiling (instantaneous) concentration above which people should not be exposed. These TLVs are identified with a "C":

5.45.1 TLV-C Threshold Limit Value-Ceiling: The concentration that should not be exceeded during any part of the working exposure.

5.46 Toxicity The ability of a substance to cause damage to living tissue, impairment of the central nervous system, severe illness, or death when ingested, inhaled, injected, or absorbed through the skin. (See also Poison, this section.)

5.47 TWA Time-Weighted Average: Unless otherwise noted, this refers to concentrations for a normal 8-hour work day and a 40-hour work week. NIOSH utilizes TWAs for up to a 10-hour work day during a 40-hour work week. (See PEL, REL, and TLV, this section.)

5.48 UEL or UFL Upper Explosive Limit or Upper Flash Limit or Upper Flammability Limit: The concentration of a substance in air at STP above which the substance is not capable of causing an explosion or flash.

5.49 Vapor Pressure (VP) The pressure (in millimeters of mercury) characteristic of a vapor in equilibrium with its liquid or solid form. It is typically given for 20 C unless otherwise noted. The VP of a chemical relates to its speed of evaporation. For example, since xylene has a higher VP than 2-ethoxyethyl acetate, it will evaporate faster. If equal quantities of xylene and 2-ethoxyethyl acetate were spilled, higher airborne concentrations of xylene would result. (See Volatility, this section.)

5.50 VOC Volatile Organic Compound: Any volatile compound of carbon.

5.51 Volatility The tendency of a solid or liquid material to pass into the vapor state at a given temperature. Specifically, the vapor pressure of a component divided by its mole fraction in the liquid or solid.

5.52 Water-Reactive A chemical that reacts with water to release a gas that is either flammable or presents a health hazard.

SECTION 6

HAZARD COMMUNICATION PROGRAM

This program provides for the three elements that form the basis of a comprehensive Hazard Communication Program (HAZCOM) as described in the Occupational Safety & Health Administration's (OSHA) Hazard Communication Standard 29 Code of Federal Regulations (CFR) 1910.1200:

1. Labeling hazardous chemicals.
2. Maintaining Material Safety Data Sheets (MSDSs).
3. Training employees.

The MDL's Safety Engineer is the designated HCP Coordinator for the Microdevices Laboratory, and is therefore responsible for implementing all phases of this program. The program for JPL is administered through JPL's OSO office.

This HAZCOM is available upon request to employees, their designated representatives, OSHA, and NIOSH in accordance with the requirements of 29 CFR 1910.20(e). The MDL HAZCOM is kept on file in the MDL Safety Engineer's office.

6.1 PERSONNEL RESPONSIBILITIES

6.1.1 Personnel must comply with all occupational safety and health standards, including the requirements of this HCP and the MDL Safety Manual.

6.1.2 Personnel must consult with their supervisor, or other appropriate management personnel, whenever there are any questions regarding this HAZCOM or the protection provided under it.

6.1.3 Employees are required to wear all recommended safety equipment to comply with the California Code of Regulations (CCR) Title 8, Chap. 4, as specified in MDL safety training and Section 9 of this manual.

6.2 CONTAINER LABELING

For the purposes of labeling, a container is defined as any bag, barrel, bottle, can, cylinder, drum, reaction vessel, storage tank, or the like that contains a hazardous chemical. Pipes and plumbing systems are not considered to be containers.

Labels for containers are available in 302-150 and 302-211 or from the MDL Safety Technicians or MDL Safety Engineer.

Container labeling will be regulated by the following:

6.2.1 Any person receiving chemicals in MDL shall ensure that labels on containers of hazardous chemicals are not missing or defaced. If such containers are found, they

shall not be released until the container is marked with proper label information. Any MSDSs received with incoming shipments shall be forwarded to the MDL Safety Engineer for review.

6.2.2 The MDL Safety Engineer shall ensure on a monthly basis that labels on containers of any hazardous chemicals remain legible and prominently displayed.

6.2.3 Notices will be posted in key areas of MDL that explain the in-house container labeling system.

6.2.4 Labeling on outgoing containers of hazardous waste chemicals shall be tagged or marked with the identity of the hazardous chemical(s) (ref. Sec. 9.5).

6.2.5 Containers from outside vendors are required to have labels that contain:

- The identity of the hazardous chemical(s).
- The appropriate hazard warning(s).
- The name and address of the chemical manufacturer, importer, or other responsible party.

6.2.6 In-house containers are considered to be properly labeled if they contain the following information:

- Identity of the hazardous chemical(s).
- Appropriate hazard warning(s).
- Symptoms of acute exposure.
- Symptoms of chronic exposure.
- First aid procedures.

Exceptions: Containers into which chemicals are transferred, and which are intended only for the immediate use of the person performing the transfer, need not be labeled. The user must not leave the unlabeled container unattended for any amount of time. Portable containers with residual chemical(s) must be labeled.

6.3 MATERIAL SAFETY DATA SHEETS (MSDSs)

Additional information on MSDSs is contained in Section 4.12 of this document.

6.3.1 MDL will maintain an MSDS with the MDL Safety Engineer for each hazardous chemical present in MDL.

6.3.2 Personnel are responsible for becoming familiar with the MSDS for each chemical with which they work.

6.3.3 Chemicals that are produced in MDL shall have an MSDS developed in accordance with paragraphs (g)(2) through (g)(5) of 29 CFR 1910.1200. Hazard determination shall be performed with the assistance of the JPL Occupational Safety Office, the MDL Safety Engineer and, as needed, certified safety consultants.

Exceptions: Mixtures or compounds produced in MDL through certain processes, such as MBE, CVD, or ion implantation, which do not increase in reactivity or hazard rating from that which is specified for the individual ingredients used, may be exempt from this standard.

6.4 INFORMATION AND TRAINING

6.4.1 Training Policies
Training of and information dispersal to employees will conform to the following:

6.4.1.1 All MDL personnel are required to attend the Section (384 & MDL) Safety Training before being allowed to perform any technical work within MDL.

6.4.1.2 The Section (384 & MDL) Safety Training is given annually in an all-hands meeting by the MDL Safety Engineer.

6.4.1.3 New hires and personnel not present at the training meeting will view applicable training video tapes prior to performing technical work in MDL.

6.4.1.4 Each employee who will perform technical work in MDL will take a test on the Section (384 & MDL) Training course and must obtain a passing grade of 85% or better.

6.4.1.5 Personnel who will need non-escorted access to the H-6 area and will not be working with hazardous chemicals will go through a safety and cleanroom protocol briefing by the MDL Safety Engineer, the MDL Manager, or a designated alternate prior to being given access authorization. (Ref. Appendix 19.)

6.4.1.6 Before entering the cleanroom envelope, all personnel must comply with the requirements described in Section 15 of this document.

6.4.1.7 An attendance roster of each Section (384 & MDL) Safety Training course will be maintained on file as a means of tracking employee participation. The MDL Safety Engineer is the custodian of these records.

6.4.1.8 Refresher courses will be given throughout the year as appropriate for specific tasks.

6.4.1.9 Employees involved in hazardous jobs, such as gas handlers and Floor Wardens, will be given additional individual training for those specific tasks.

6.4.2 Description of Courses

6.4.2.1 Annual Section (384 & MDL) Safety Training
The annual Section (384 & MDL) Safety Training Program covers all technical areas (both within and outside of MDL) which are under the control of Section 384. The annual Section (384 & MDL) Safety Training is divided into three sessions. All personnel are

required to attend the first session including administrative management, secretarial, supervisory, and technical personnel. The first session covers General Safety Information and typically includes:

- Section (384 & MDL) Technical Area / Safety Overview
- Legal Requirements, Rights and Responsibilities, including:
  - Hazard Communication Standard / Chemical Hygiene Plan
  - MSDSs and other reference material
- Non-technical Area Safety
  - Ergonomics
- Emergency Preparedness
- Emergency Response

The second session is required of all MDL technical users and Section 384 technical personnel, including supervisory personnel. The session covers General Technical Area Safety Information and typically includes topics on:

- Electrical Safety and Lockout / Tagout
- Personal Protective Equipment
- Hazardous Waste Management (& Labeling)
- Pre-OSRs
- Safety Training Requirements (& available JPL classes)

The third session is required of all MDL technical users. This session covers specific MDL chemical hazards and MDL specific safety training and will typically present information covering:

- Chemical Hazards:
  - Presentations from various MDL Processors
- MDL Safety Manual
- Accidents & Incidents (with Lessons Learned)
- Questions & Answers

Additional safety training presentations / specific hazard discussions at individual group meetings are also planned for every technical group within Section 384 to provide an additional forum to present and discuss topics and procedures of a lab specific nature (such as compressed gas cylinder safety and handling procedures; vacuum system safety; etc.).

6.4.2.1.1 Employees who deal with lasers will require additional training and a refresher course every two years. These classes are administered through the JPL Occupational Safety Office. Registration may be done electronically. (See also Section 13.)

6.4.2.1.2 Employees who require the utilization of respirators in their work must complete 3 steps annually to be certified for their use (See also Section 9.2.4.):

1) Medical Surveillance verifying health. (Submit "Medical Surveillance Request Form (JPL 2633-S)" (See Section 4.20), through supervisor.)
2) Respirator Training
3) Respirator Fit Test (Contact JPL Occupational Safety Office).

In addition, respirator users must obtain respirator uses and responsibilities training by the MDL Safety Engineer / Section 384 Safety Coordinator.

6.4.2.2 Warden and Gas Handler Training
All MDL wardens are required to take:

- JPL Warden Training
- Fire Extinguisher Training
- First Aid and CPR Training

In addition to the required training specified above and in Section 6.4.2.1 (i.e. Annual Section (384 & MDL) Safety Training – all parts), it is also recommended and encouraged that the MDL gas handlers, MDL first floor wardens, MDL building warden, and alternates take :

- Respirator Training
- Self Contained and Supplied Air Breathing Apparatus Training
- Gas Cabinet Control Systems Training
- Chemical Spill Control (Small Spills).

6.4.2.3 Machine Shop Operator Training (See 14.3.1.2 & 14.3.4.5)
It is highly recommended and encouraged that machine shop operators take Fire Extinguisher Training.

6.4.3 Outside Contractor Training

The following training requirements and responsibilities pertain to all outside contractor personnel who access MDL. This includes outside contractors and JPL Facilities personnel who must sometimes service equipment and facilities within the Microdevices Laboratory (MDL).

6.4.3.1 JPL / MDL Responsibilities:
The MDL Safety Engineer, along with the JPL Occupational Safety Office (OSO), will be responsible for providing outside contractors instructions related to:

- Hazardous chemicals to which they may be exposed while on the job site.
- Measures that the contractor employees may take to lessen their possibility of exposure.
- Steps that have been taken to lessen the risks of exposure.
- The location of MSDSs for all hazardous chemicals.
- Procedures to follow if the contractor is exposed.
- Evacuation procedures.

(See template training materials for contractors & visitors in Appendix 19.)

6.4.3.2 Contractor Responsibilities
Contractors will be responsible for knowing and complying with:

- Applicable regulatory requirements that the contractor will be required to follow while performing work.

• Specific JPL rules, regulations, policies, and procedures that must be complied with while working at JPL.
• Supplying the MDL Safety Engineer with MSDS information for all chemicals that the contractor brings on Lab.
• Supplying the MDL Safety Engineer and the JPL OSO with the contractor's company's Safety Plan.
• Signing in and out on the MDL Maintenance and Facilities Sign-In Log as specified in Section 4.11.

SECTION 7

CONFIGURATION CONTROL

7.1 SCOPE

The MDL Configuration Control process is designed to facilitate complete tracking of any changes, additions, deletions or modifications introduced into the building, including the updating of drawings and specifications.

The Configuration Control process is required for any and all changes, additions, deletions or modification to:

- Technical processes and operations involving acutely hazardous materials (AHMs)
- Technical equipment dealing with AHMs.
- The MDL life safety systems
- Base building equipment
- The MDL structure

The Configuration Control Group will be responsible for assuring that all aspects of additions, modifications, changes or deletions introduced into the system conform to the operational and system safety program requirements of MDL. (See also Sec. 3.2).

7.2 CONFIGURATION CONTROL GROUP CHARTER

7.2.1 The three principal multifaceted organizational elements involved in the Configuration Control process are:

- The MDL Configuration Control Group consisting of the MDL Safety Engineer, MDL Facilities Engineer, and MDL Manager (providing local knowledge, oversight and control)
- JPL Facilities and Plant Engineering (providing facilities expertise and support)
- JPL OSO, JPL EAO, JPL Occupational Health, JPL Fire, and JPL Security (providing safety and environmental expertise and support)

7.2.2 Other groups or individuals may be added to the Configuration Control Group (CCG) as individual circumstances arise.

7.2.3 Configuration Control will at a minimum address the following where applicable:

- Documentation, typically including:
  - general system description, layout, and safety features.
  - standard operating procedures
  - preventive maintenance schedules.
  - emergency shutdown procedures.
  - piping and instrumentation diagrams.
  - reports on post installation leak checks, tests, and results.

- Training as described in Section 6.4 of this manual.

- Regulatory Compliance at local, State, and Federal levels.

- Auditing on a periodic basis of safety policies and equipment and facility documentation.

- Each modification or addition shall be reviewed for control technology requirements (monitor-alarm-control).

- Each change, modification, addition or deletion will be reviewed for its impact on existing operations and the capability of the installed building system's capacity to provide the required utilities.

7.3 FACILITY AND EQUIPMENT MODIFICATIONS AND HAZ-OP REVIEWS

7.3.1 All Facilities Service Requests (FSRs) will be coordinated through the MDL Facilities Engineer (also see Section 8).

7.3.2 All changes, additions, deletions, or modifications to technical equipment must be coordinated through the MDL Manager.

7.3.3 Changes or modifications to technical equipment or operations that affect the operational description in the Pre-OSR (Section 4.17) require a new Pre-OSR describing the intended operation. This must be coordinated through the MDL Safety Engineer.

7.3.4 Additions, deletions, changes, or modifications to technical equipment or operations that involve AHMs will require a Hazard and Operability (Haz-Op) review as part of the configuration control approval process.

7.3.4.1 The requirements for a Haz-Op review will be determined on an individual basis. A typical Haz-Op team will include the Cognizant Engineer, the MDL Safety Engineer, the MDL Manager, the MDL Facilities Engineer, a member of OSO, a member of EAO, and at least one additional knowledgeable engineer from the group originating the FSR.

7.3.4.2 The MDL Safety Engineer will inform the Cognizant Engineer of these requirements.

7.3.5 Changes, additions, deletions or modifications to equipment utilities that are hard wired or hard plumbed must go through the Configuration Control process, which includes but is not limited to a safety analysis.

7.3.6 Any changes, additions, modifications or deletions of MDL utilities to equipment or hardware must go through the Configuration Control process.

7.3.7 Any physical changes, additions, deletions or modifications to the MDL structure (bulkheads, wall partitions, overheads, ceilings, cleanroom feedthroughs, etc.) must go through Configuration Control (see also Section 8).

7.3.8 Any unauthorized change, modification, addition or deletion to the MDL life safety system is strictly forbidden. Proposed changes or modifications may be submitted for consideration to the MDL Configuration Control Group through the MDL Safety Engineer or the MDL Manager. Specific elements of the MDL life safety system subject to Configuration Control include:

- Toxic/pyrophoric/mineral acid gas detection system
- Combustible gas/oxygen deficiency detection system
- Seismic detection system
- Manual emergency shutoff for hazardous gases
- Fluid leak detection system
- Smoke, flame and heat detectors
- Red mushroom (panic) buttons
- Incipient fire detection system
- Fire alarm control panel
- Fire alarm pull stations
- Exhaust failure detection system
- Emergency power generators
- Fire detection / suppression systems for building and wet stations
- Gas cabinets
- Nitrogen purge systems
- Emergency nitrogen and general-purpose nitrogen
- Pendant alarm system (i.e. electronic buddy system)
- Door alarms for hazardous gas bunker and emergency exits
- Annunciator panels, horns, and strobe lights (i.e. alarm indicating devices)
- Public address speakers and emergency paging system
- Uninterruptible Power Supply (UPS) system

7.4 IMPLEMENTATION OF CHANGES, ADDITIONS, DELETIONS, AND MODIFICATIONS

7.4.1 Change requests are formally initiated by the cognizant Technical Group Supervisor to the MDL Manager. Prior to initiation of any changes, an initiation review shall be conducted by the Cognizant Engineer, the cognizant Technical Group Supervisor, the MDL Manager, and the MDL Safety Engineer. This review begins with informal discussions and encompasses issues including utilities requirements, hazard potential, schedule, budget, floor space constraints, and any other special requirements that may be associated with the Change Order (C/O) request.

7.4.2 After change approval has been granted and all required documentation has been supplied by the requester, the documentation will be forwarded or presented to the

Configuration Control Group (CCG) for review. (See Sec. 3.2.2 for constitution of the CCG.)

7.4.3 The CCG will generate a brief report describing the outcome of the review, including:

- Compliance with current specifications, design requirements, operational requirements, codes, and regulations.
- A description of modifications required by the CCG, if any.
- Potential hazards associated with the installation aspects (e.g., tapping into toxic or pyrophoric gas lines, etc.).
- Potential risks to operations (e.g., installations within the cleanroom envelope, etc.).

7.4.4 Upon approval by the CCG, the change or modification request and any required Facilities Service Requests (Section 4.9) will be forwarded to the appropriate group or section for implementation.

7.4.5 Upon completion of the changes or modifications, the Cognizant Engineer, along with the CCG, will perform validation tests for verification that all aspects of the CCG review were performed according to the stated specifications.

SECTION 8

FACILITIES AND UTILITIES

All issues regarding MDL facilities and utilities are under the cognizance of and should be directed through the MDL Facilities Engineer.

8.1 CENTRAL UTILITIES

The following utilities are available throughout the H-6 areas:

- Ultrahigh-purity DI water (supply and return)	16 - 18 Megohms resistivity / 30 psig / 25 gpm capacity
- Process cooing water (supply and return)	60 F / 85 psig
- City water	140 psig
- Compressed dry air (CDA)	125 psig rating, 95-115 psig supplied
- Process vacuum	25-28 in. Hg
- Ultrahigh-purity nitrogen	100 psig
- Ultrahigh-purity oxygen	15 psig
- Liquid nitrogen	Tank 23 = 1300-gal + Tank 26 = 900-gal plus gaseous source nitrogen from Tank 27 = 3000-gal.
- General-purpose gaseous nitrogen	125 psig

8.2 EFFLUENT SYSTEMS

8.2.1 Inorganic Exhaust

The inorganic exhaust system has an installed capacity of 37,810 CFM. The duct material is fiberglass-reinforced polyester (plastic) (FRP) with integral fire sprinklers for segments with diameters greater than 10 inches.

The inorganic vapor effluent passes to a wet scrubber. The chemical fumes entering the scrubber are scrubbed by an intensive spray of a chemical (pH 8.0 or greater) solution through a system of special nozzles and a recirculation pump. Make-up water is provided through a 0.5-inch water inlet. A float valve regulates the make-up water volume to maintain a constant level in the tank.

8.2.2 Organic Exhaust

The organic exhaust system has an installed capacity of 13,000 CFM. The duct material is spiral-seamed, galvanized steel.

8.2.3 Vacuum Pump Exhaust

Vacuum pumps associated with processes not using hazardous production materials (HPMs) are connected to the vacuum pump exhaust system. The installed capacity of this system is 8,100 CFM. The duct material is stainless steel.

8.2.4 Combustion Decomposition Oxidation Units (CDOs) & Local Wet Chemical Scrubbers

All systems (except the MOCVD, MOVPE, or OMVPE reactors) handling gases listed as AHMs, pyrophoric materials, or hydrogen at concentrations in excess of the LEL (4.0%), are connected to the inorganic scrubbed exhaust system through a CDO and a minimum of 10 feet of stainless steel exhaust line. The MOCVD, MOVPE, or OMVPE reactors are connected to the inorganic scrubbed exhaust system through local wet chemical scrubbers. The CDOs and scrubbers insure that any unreacted pyrophoric, toxic, or flammable material from the process chamber is fully reacted prior to entering the inorganic exhaust system. The additional 10 feet of stainless steel exhaust line serves as a temperature barrier between the CDO, which runs at approximately 900 C, and the FRP ducting material of the inorganic exhaust system. Service procedures are listed in Appendix 16.

8.3 AIR HANDLERS

There are five main air handlers for MDL (AH1, AH2, AH3, AH4 & AH5). They are in the equipment room (302-236) on the second floor. An additional Recirculation Unit, AH6, has been added to 302-101C.

Air Handler 1 (AH1) is the main air intake for air into the 1st floor pressing areas. It prefilters the air to class 100,000 (ISO 8) levels, controls the humidity of the air, and redistributes it to 32 recirculating units in the 2nd floor plenum area (these units further filter the air to class 100 (ISO 5), and 10 (ISO 4) levels); to AH3, AH4, and to AH5.

AH2 has a separate air intake and provides air to the office areas on the 2nd and 3rd floors.

AH3 receives class 100,000 (ISO 8) air from AH1, refilters it, and supplies and recirculates air to the light lab areas in the north side of the 1st floor.

AH4 receives class 100,000 (ISO 8) air from AH1, refilters it, and supplies and recirculates air to rooms 302-143, 147, and 150 on the 1st floor.

AH5 receives class 100,000 (ISO 8) air from AH1 and supplies the air with no recirculation or refiltering to the MOCVD processing area (302-153).

AH6 (RCF1 in 302-101C facilities DWGS) receives class 100,000 (ISO 8) air from AH3 and recirculates air to the expanded class 100 (ISO 5 – classified as ISO 6 in this instance due to non-unidirectional air flow) areas: 302-101A and 302-101B.

8.4 SAFETY SYSTEM

8.4.1 MDL Life Safety System

The MDL Life Safety System (see also Section 16.6.7) is supervised in a two-tiered system consisting of:

1. The JPL Emergency Console (manned 24-hours)

2. The MDL Monitoring and Control Room (302-139), through which the following subsystems are monitored:
   - Toxic / pyrophoric / corrosive gas detection
   - Combustible gases / oxygen deficiency detection
   - Seismic detection
   - Red mushroom buttons (panic buttons)
   - Fluid leak detection
   - Fire / smoke / heat detection
   - Incipient fire detection system
   - Pendant alarm system (electronic buddy)
   - Exhaust system failure detection
   - Emergency power generator
   - Fire-suppression system for wet stations
   - Gas cabinet purge panels for hazardous gases
   - Acid waste line effluent pH
   - Emergency and general-purpose nitrogen
   - Process cooling water system
   - Door alarms for hazardous gas bunker and emergency exits
   - Operational status of CDOs and scrubbers.

8.4.2 Hazardous Gases and Gas Cabinets

8.4.2.1 The MDL complies with the intent and prevailing interpretations of the requirements contained in the Uniform Fire Code and other regulatory documents as related to compressed gases.

8.4.2.2 The MDL safety system will issue an emergency shutdown signal to all hazardous gases at their source upon any of the following conditions of sufficient magnitude:

- Toxic / pyrophoric gas detection
- Combustible gas detection
- Seismic disturbance
- Fire / smoke / heat detection
- Exhaust system failure
- Building power failure
- Activation of any manual emergency shutoff station
- Remote intervention by JPL Security/Fire officials
- Excess flow
- Excess delivery pressure

8.4.3 Fire Protection

8.4.3.1 The main fire alarm control panel is located in the communication equipment room, 302-111.

8.4.3.2 The emergency shutdown for electrical power is located on the second level at the east end of the main corridor.

8.4.3.3 Pull stations are located at stairways that exit the first and third floors and at all personnel exits.

8.4.3.4 Smoke detectors have been installed in all air supply and return ducts, recirculation units, tops of stairwells, elevator landings, repro rooms, communication equipment rooms, first floor B-2 area, class 100,000 (ISO 8) H-6 areas, and in the elevator shaft. In addition, a state-of-the-art Incipient Fire Detection System monitors room air from the entire H-6 area.

8.4.3.5 Water-flow switches and tamper switches have been utilized throughout the building fire sprinkler piping.

8.4.3.6 The building has been divided into several incipient fire alarm zones and smoke/heat fire alarm zones (see Building 302 Blueprint No. CD-E5.2).

8.4.3.7 Hose cabinets are located at the entrance to the east stair wells on all floors as well as at the top of the third floor west stairwell, the second floor entrance to the second-third floor west stairwell and the base of the first floor west stairs. Note that hoses have been removed, but that connections may be accessed and utilized by Fire Dept. (trained) personnel only, as per NASA directive in NASA Safety Standard (NSS) 8719.11 for fire protection..

8.4.3.8 Standpipe outlets are located in the east stair well and in hose cabinets on the west end.

8.4.3.9 A sprinkler connection is located at the north-east end of the building close to the street.

8.4.3.10 Smoke dampers are located throughout the building ventilation systems.

8.4.3.11 The activation of any pull station, heat detector, smoke detector, or high IFD point will:

- Be automatically communicated to (annunciated in) the JPL Emergency Console. If an evacuation alarm sounds, the building warden or designated alternate, or in their absence, any available person will verify alarm transmission once evacuation of the building has been completed. This may be accomplished by dialing 911 (or 393-3333 for cellular phones) or through direct radio communication with the JPL Emergency Console. [Note that dialing 911 on a JPL phone within the boundaries of JPL (or 393-3333 on a cellular phone) will connect with JPL specific, local emergency responders.]

- Activate the appropriate zone indicator on the annunciator panels.

- Sound a general alarm over all evacuation horns in all zones

- Select the appropriate fans for operation in smoke removal

- Activate fire dampers as required.

8.4.4 Public Address

The MDL public address system is accessed either by JPL emergency announcements or in an "MDL only" mode by dialing 168 from any phone in the H-6 area or in one of the secretarial areas on the second and third floors. The JPL Emergency Console can also access the MDL public address system. Emergency assistance from the MDL Floor Wardens may be obtained by using the MDL emergency paging system.

SECTION 9

CHEMICAL POLICIES

9.1 POLICIES

9.1.1 The MDL Safety Engineer will be informed of all chemicals or compounds that are produced in or delivered to MDL.

9.1.2 Chemicals that have not been inventoried by the MDL Safety Engineer will not be allowed in MDL.

9.1.3 The MDL Safety Engineer will maintain an inventory plan and a MSDS for all chemicals used in MDL. MSDSs are available at all times in the yellow binders in the MDL Lobby (302-200) just outside the MDL Library (302-211).

9.1.4 Container Labeling:
Exceptions: Portable containers that are intended only for the immediate use of the employee and will be attended at all times need not be labeled. Portable containers with residual chemicals or chemicals left unattended must be labeled.

9.1.4.1 Labels on containers (including beakers and other interim-use lab ware) in MDL laboratories will be labeled with the following information:

- Identity of the hazardous chemical(s) contained therein.
- Appropriate hazard warning(s).
- Symptoms of acute exposure.
- Symptoms of chronic exposure.
- First aid procedures.

9.1.4.2 Labels for containers are available in 302-150 and 302-211 or from an MDL Safety Technician.

9.1.4.3 Waste chemical container labeling is described in Section 9.5.

9.1.4.4 Labeling requirements for specialized chemicals which researchers desire to be retained beyond their normal expiration date (a special circumstance which is an exception to standard practices requiring approval by MDL management) is described in Section 15.2.10.

9.1.5 Chemicals that are stored within the same cabinet or storage compartment must be compatible with each other as described in the MSDS. (See also Appendix 20.)

9.1.6 All chemical operations require an approved Pre-OSR form (Section 4.17 of this document).

9.1.7 The following is a list of gases used in MDL that are designated as acutely hazardous materials (AHMs);

Phosphine (PH_3)	Arsine (AsH_3)
Hydrogen chloride (HCl)	Boron trichloride (BCl_3)
Ammonia (NH_3)	Chlorine (Cl_2)
Diborane (B_2H_6)	

The specific hazards, use and handling of these gases are defined in detail in Section 10 and Section11 of this manual.

9.1.8 All liquid hazardous chemical operations shall be performed in a ventilated wet chemical station (bench)/hood or glove box.

9.1.8.1 In the MDL clean rooms solvent operations are to be performed on the stainless steel wet processing stations (benches). Acid and corrosive operations are to be performed on the white polypropylene wet processing stations (benches).

9.1.8.2 The outsides of acid and caustic bottles shall be rinsed after use to remove residue. Also, rinse down work areas after use. For spills contact the nearest floor warden and the MDL Safety Engineer or the MDL Manager (see Section 16.4.2).

9.1.8.3 Chemical wet processing stations (benches)/hoods shall be tested annually for adequate ventilation and labeled with the date and test results.

- Benches/hoods that do not pass this test shall be shut down until the problem is corrected.
- All sash and damper settings shall be marked at the position that satisfies the ventilation requirements.
- Down flow wet-processing stations in the clean rooms will be checked periodically for adequate capture.

9.1.8.4 All chemical benches/hoods and chemical storage cabinets shall have an attached list of all chemicals and quantities permitted (Chemical Inventory Form, Section 4.3 of this document).

9.1.8.5 Contact lenses are not permitted when performing wet chemical operations. Prescription safety glasses are available through the JPL Occupational Safety Office. Contact the MDL Safety Engineer for further information.

9.2 PERSONAL PROTECTIVE EQUIPMENT (PPE)

In general, personal protective equipment requirements for operations involving hazardous materials shall comply with JPL standards, MSDS information, OSHA requirements, and prudent industry-accepted safety practices.

Only personal protective equipment issued by or approved by JPL and MDL may be used in MDL.

MDL will provide personal protective equipment appropriate for hazardous operations in accordance with all applicable standards. In some cases specialized protective equipment required for an operation will have to be purchased by the cognizant group. This protective equipment will be subject to approval by JPL OSO and the MDL Safety Engineer.

All protective equipment except aprons and face shields should have a single user and should be labeled with the user's name.

9.2.1 Wet chemical operations [to be performed in an exhausted fume hood/wet processing station (bench)] will require the following protective equipment:

- Goggles (This item is to be personalized with your name) are mandatory.
- Face shields are mandatory.
- Appropriate gloves (This item is to be personalized with your name) are mandatory.
- Aprons are mandatory.
- Sleeve protection (This is optional, but required for any work involving highly corrosive materials or where specified in the MSDS.)

Optional foot protection is available from the MDL Safety Engineer. It is required whenever there is a heightened potential of a spill of hazardous chemicals. Sandals or open-toed shoes are prohibited.

Note that some minor chemical solvent cleaning operations will not require PPE, but the use of goggles is recommended in all instances. Questions concerning PPE requirements for any given operation should be raised to the MDL Safety Engineer or an MDL Safety Technician.

9.2.2 CRYOGENIC OPERATIONS

Note: Liquid nitrogen left in a container open to the atmosphere will absorb or condense other room gases into it. This liquid nitrogen/liquid air mixture is much more likely to burn skin tissue on contact than liquid nitrogen alone.

Cryogenic operations (more than 1 gallon of liquefied nitrogen or any quantity of any other liquefied gas) as a minimum will require:

- Eye protection (goggles recommended)
- Face shield
- Appropriate gloves (cryo-gloves)
- Apron (cryo-apron)
- Monitoring at all times for filling and dispensing operations.
- Cryogenic operations (less than 1 gallon of liquefied nitrogen) as a minimum will require:
- Cryogenic gloves
- Eye protection (goggles and face shield recommended)

9.2.3 Laser (class 3 and 4) and UV light radiation will as a minimum require appropriate safety glasses. No jewelry, watches, or any other specular reflective objects should be worn in laboratories where class 3 or 4 lasers are being operated.

9.2.4 Air Purifying Respirators (See also Section 6.4.2.1.2).

9.2.4.1 Only respirators issued by JPL OSO or the MDL Safety Engineer (in conjunction with the JPL OSO) may be used in MDL.

9.2.4.2 Respirators shall be used in operations where engineered methods to control air contaminants are not practical.

9.2.4.3 Respirators may be used only after the following requirements are satisfied:

- Medical spirometry examination and approval by JPL Occupational Health Services
- Respirator training by JPL OSO
- Respirator Fit Testing by JPL OSO
- Respirator uses and responsibilities training by the MDL Safety Engineer

9.2.4.4 Operations that require respirator protection devices shall be reviewed and if deemed necessary will have an airborne contaminant test run to verify that the specified respirators provides adequate protection.

9.2.4.5 Respirators shall be issued on an individual basis.

9.2.4.6 Respirators shall be personalized with the user's name.

9.2.4.7 When not in use, respirators shall be kept in a sealed bag marked with the user's name and stored out of the hazardous environment in a clean, sanitary, and easily accessible area.

9.2.4.8 Respirators shall be cleaned before and after every use. Respirator wipe pads are available from the MDL Safety Engineer or MDL Safety Technician.

9.2.4.9 Respirators shall be inspected for deterioration and damage prior to and after each use.

9.2.4.10 Respirator Cartridges shall have designated schedule change-outs.

9.2.5 Gloves

9.2.5.1 Gloves should be selected on the basis of the hazardous material being handled. Appropriate glove selection charts and information are available through the MDL Safety Engineer or an MDL Safety Technician.

9.2.5.2 Before each use, gloves should be inspected for degradation (e.g. discoloration, punctures, cracks, tears, etc.).

9.2.5.3 Before removal, gloves should be rinsed appropriately and dried.

9.2.5.4 Gloves should be replaced periodically depending on frequency of use, permeability, and physical integrity as described in paragraph 9.2.5.2 above.

9.3 REQUISITIONS

9.3.1 All outside vendor chemical orders shall be channeled through the MDL Safety Engineer or designated alternate for review and approval.

9.3.2 All JIT chemical orders shall be routed through the MDL Safety Engineer or designated alternate for review and approval.

9.3.3 Chemicals that arrive as free samples or from other research labs must be accompanied by an MSDS and reported to the MDL Safety Engineer or MDL Safety Technician.

9.3.4 Orders for chemicals must not exceed the maximum quantity specified per storage area.

9.3.5 All chemicals for use in MDL shall be delivered first to room 302-150.

9.4 DISTRIBUTION AND STORAGE

Exceptions: Within a processing bay, a glass bottle of acid or solvent may be carried in the approved plastic chemical carrier available from an MDL Safety Technician. Plastic solvent containers may be carried from in-use storage to a point-of-use wet bench.

9.4.1 All liquid chemicals shall be transported from the Chem Prep Room (150) to the point of use in the approved chemical safety carriers or chemical transport carts.

9.4.2 Only one chemical container may be hand-carried at one time.

9.4.3 A five gallon carboy is the largest chemical container that may be carried by hand.

9.4.4 Multiple containers shall be transported in white polypropylene chemical carts (for corrosives and oxidizers) or stainless steel chemical carts (for combustible and flammable liquids).

9.4.5 Hazardous chemicals may not be transported in personal vehicles.

9.4.6 Chemicals that are stored together must be compatible. Information is available through the MDL Safety Engineer or the appropriate MSDS. A chemical compatibility table may be referenced in Appendix 20.

9.4.7 Hazardous chemicals must be stored in approved storage containers.

9.4.8 Adding chemicals or increasing quantities above that specified on the storage hood or cabinet must be coordinated through the MDL Safety Engineer or an MDL Safety Technician.

9.5 HAZARDOUS WASTE HANDLING

9.5.1 GENERAL

9.5.1.1 At the time a hazardous waste container is first used, the user is responsible to label the waste container.

9.5.1.2 Labeling requirements:

- If a previously used container is used, the old label must be made completely illegible (i.e. obliterated).
- The hazardous waste label must be legible.
- The content description must be complete and specific, including trade names, if applicable.

- Hazardous waste labels must include:
    - The words "HAZARDOUS WASTE"
    - Name of chemical(s)
    - Physical state
    - Hazardous property(s)
    - The concentration (if known) for mixtures
    - The user's name
    - The date waste collection starts.

9 5.1.3 The label information may be written directly on the container, or on blank labels available in the clean room as well as in room 302-150. (Ref. Section 4.10 and Appendix 6). Note that clean room compatible label materials must be utilized within the certified MDL clean room areas.

9.5.1.4 Only compatible wastes, as specified by the MSDS, will be placed within a single container. If there are any questions regarding compatibility, contact the MDL Safety Engineer.

9.5.1.5 Waste containers shall not be filled to more than 3/4 capacity.

9.5.1.6 Liquids spilled or splashed on the outside of the container must be cleaned off immediately.

9.5.1.7 Wipes or pads used to clean off hazardous materials are to be treated as hazardous solid wastes and disposed as described in Section 9.5.5 of this document.

9.5.1.8 Chemical waste containers will be collected for disposal after 30 days or when the container is 3/4 full, whichever comes first.

9.5.1.9 The users are responsible for moving full waste containers from the cleanroom envelope to the appropriate chemical pass-through cabinets located at the east end of the cleanroom corridor 302-135.

9 5.1.10 The users are responsible for moving full waste containers from the light labs (302-101 through 302-108) and the class 100,000 (ISO 8) areas to the appropriate cabinet or chemical hood in the chemical entry room (302-150).

9.5.1.11 MDL Safety Technicians are responsible for coordinating hazardous waste removal from building 302 by the JPL Environmental Affairs Office (EAO). A Hazardous Waste Disposal Form (see Section 4.10 and Appendix 6) is required for this operation. Forms are available from the JPL EAO.

9.5.1.12 In Section 384, for chemical operations outside of MDL, the Cognizant Engineer is responsible for coordinating hazardous waste removal with the JPL Environmental Affairs Office. A Hazardous Waste Disposal Form (see Section 4.10 and

Appendix A6) is required for this operation. Forms are available electronically or from the JPL EAO.

9.5.1.13 All hazardous waste containers shall be kept closed except when filling or emptying.

9.5.2 SOLVENTS

9.5.2.1 Chlorinated and fluorinated solvents are considered halogenated solvents. Halogenated solvent wastes will be collected individually in a glass container or specially provided high-density polyethylene waste containers.

9.5.2.2 Plastic containers used in shipping nonhalogenated solvents (e.g.: acetone, methanol, etc.) are attacked by TCE and other halogens and should not be used for halogenated solvents.

9.5.2.3 In-use waste containers shall be stored in the corresponding in-use solvent bench or in a solvent cabinet.

9.5.2.4 Removal of hazardous waste containers will be handled as per Section 9.5.1 of this manual.

9.5.2.5 Nonhalogenated solvent wastes are collected in the right-hand-side solvent carboys located underneath each solvent bench (accessed through the center sink drain).

9.5.2.6 Water used in the solvent benches goes into the left-hand-side carboy (15-gallon capacity) under the bench (access through the heated bath, ultrasonic tank, and glove wash). See Figure 9-1. Exception: The dump rinser water is the only water in the solvent benches which empties into the acid waste line which goes to the city sewer. The dump rinser should only be used to remove trace contaminants on the surface of substrates, etc. The dump rinser should not be used to empty solvents or water with solvents intended for collection.

9.5.2.7 Full carboys may be changed out by the users. Empty carboys are located in the clean room corridor 302-135, just outside of the thermal bay (302-136).

9.5.3 CORROSIVES and OXIDIZERS

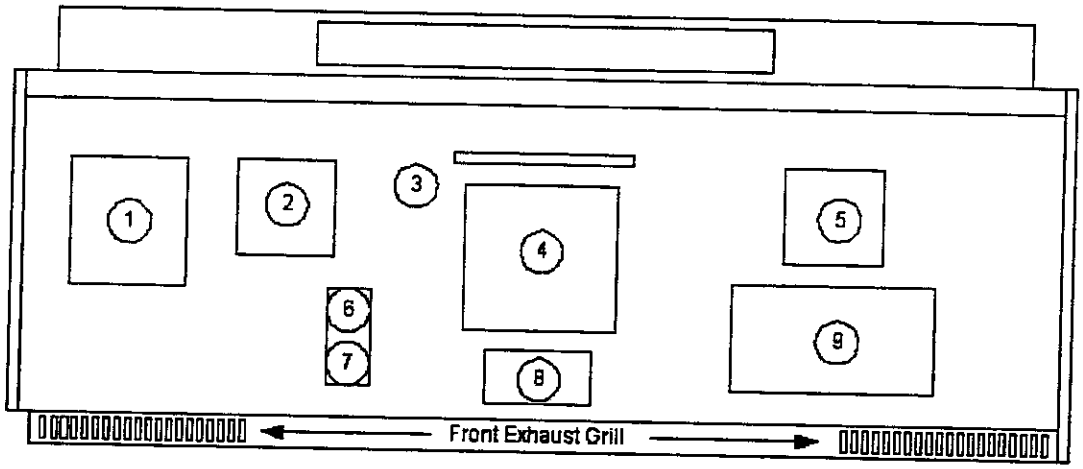
9.5.3.1 Corrosive and oxidizer wastes shall be collected only in new polyethylene containers no larger than a one-gallon capacity.

9.5.3.2 Waste containers for acid and corrosive use are available in room 302-150, the oxidizer pass-through, or from JIT.

9.5.3.3 Hazardous waste containing hydrofluoric acid should be collected in separate containers. If there are any questions on segregation or labeling, contact the MDL Safety Engineer or an MDL Safety Technician.

9.5.3.4 Removal of hazardous waste containers will be handled as per Section 9.5.1 of this manual.

9.5.3.5 Special vented caps and bottles for materials, which might generate internal bottle pressure, are available from the MDL Safety Engineer or an MDL Safety Technician.



1. Hot Plate
2. Heated Tank
3. Air Aspirator
4. Stainless sink
5. Ultrasonic Unheated Tank
6. DI Water Hand Spray
7. Glove Wash
8. Nitrogen Gun
9. Dump Rinser

Figure 9-1. Solvent Wet Chemical Processing Station (Bench) Plan View

9.5.4 OTHER LIQUID HAZARDOUS WASTES

9 5.4.1 Acid/solvent mixtures shall be collected in one-gallon polyethylene jugs, labeled appropriately and handled like corrosive waste.

9.5.4.2 Liquid wastes not covered in, Section 9.5 of this document must be reported to the MDL Safety Engineer by the user.

9.5.5 Solid and Reactive Hazardous Wastes

9.5.5.1 Solid non reactive hazardous wastes (such as arsenic, etc.) shall be double-bagged, appropriately labeled as specified in Section 9.5.1 of this manual, and placed in the toxic waste cabinet located in room 302-150.

9.5.5.2 Bags for hazardous solid waste are located in room 302-150 and the oxidizer pass-through.

9.5.5.3 For nontoxic solids contaminated by a toxic substance, write specifically what the nontoxic item is and the contaminant material (e.g. 'Tyvek coverall and vinyl gloves contaminated with arsenic," etc.).

9.5.5.4 The MDL Safety Engineer shall be consulted for the packaging for disposal of air-reactive and water-reactive wastes.

9.6 PROCEDURES FOR SPECIFIC HAZARDOUS CHEMICAL OPERATIONS

Information and procedures on a number of specific chemical operations within MDL as listed below, have been documented and may be accessed:

- Vacuum pump oil changes (Appendix 15).
- CDO change out and local Wet Scrubber solution changes (Appendix 16).
- AHM gas plumbing (Appendix 17).
- MOCVD / MOVPE servicing procedures (located at the MDL website under the tool banner).
- Specific toxic gas bottle delivery procedures (Section 11.8).
- Specific hydrogen delivery procedures to the MDL Hydrogen Bunker, 302-155 (Section 11.9).

SECTION 10

SPECIFIC CHEMICAL HAZARDS

The reader is cautioned that the primary reference material for all chemicals utilized in the Microdevices Laboratory (MDL) should be their MSDSs (See Section 4.12). The following listings and information are provided as a convenient overview of specific chemical hazards which might be encountered within MDL. Specific reference sources are not called out at each entry, although an attempt has been made to list the reference sources for TLV and STELs in italics underneath the listings, since this information can change with time, as more information becomes available. The information is drawn from numerous reference sources. Among them are:

1) NIOSH Pocket Guide to Chemical Hazards, U.S. Government Printing Office, Washington, D.C., June, 1997.
2) Baldwin, David G., Williams, Michael E., and Murphy, Patrick L., Chemical Safety Handbook for the Semiconductor / Electronics Industry, Second Edition, OEM Press, Beverly, Mass., 1996.
3) 1999 - 2000 Threshold Limit Values (TLVs) for Chemical Substances and Physical Agents and Biological Exposure Indices (BEIs), ACGIH Technical Affairs office, Cincinnati, Ohio, 1999.
4) Handbook of Compressed Gases, Third Edition, Compressed Gas Association, Inc., Arlington, VA, Chapman & Hall, New York, NY, 1990.
5) Matheson Guide to Safe Handling of Compressed Gases, Second Printing, Matheson Gas Products, Inc., Secaucus, NJ, 1983.
6) Braker, William, and Mossman, Allen L., Matheson Gas Data Book, Sixth Edition, Matheson Gas Products, Secaucus, NJ, 1980.
7) Gas Encyclopaedia, Scientific Division of Air Liquide, English translation by Nissim Marshall, Elsevier Science Publishing Company, Inc. New york, NY, 1976.
8) Lewis, Sr., Richard J., Hazardous Chemicals Desk Reference, Second Edition, Van Nostrand Reinhold, New York, NY, 1991.
9) Hodgson, Ernest, and Levi, Patricia E., A Textbook of Modern Toxicology, Appleton & Lange, Simon & Schuster Business and Professional Group, Norwalk, Connecticut, 1987.
10) Clayton, George D., and Clayton, Florence E., editors, Patty's Industrial Hygiene and Toxicology, Third Revised Edition, Vols. 2A, 2B, and 2C, John Wiley & Sons, Inc., New York, NY, 1981.
11) Masterton, William L., and Slowinski, Emil J., Chemical Principles, W. B. Saunders Company, Philadelphia, PA, 1966.
12) Cotton, F. Albert, and Wilkinson, Geoffrey, Advanced Inorganic Chemistry, Third Edition, Interscience Publishers, A Division of John Wiley & Sons, Inc., New York, NY, 1972.
13) Mahan, Bruce H., College Chemistry, Addison-Wesley publishing Company, Inc., Reading, Massachusetts, 1966.
14) Collocott, T. C., and Dobson, A. B., editors, Chambers dictionary of science and technology, Hazell, Watson, & Viney Ltd., Aylesbury, Bucks, Great Britain, 1974.

An additional reference which may be consulted for spill response is

15) 1996 North American Emergency Response Guidebook, A guidebook for First Responders During the Initial Phase of a Hazardous Materials / Dangerous Goods Incident, J.J. Keller & Associates, Inc., Neenah, Wisconsin, 1996.

10.1 ACETYLENE (C_2H_2)

- Colorless gas; ethereal odor (commercial grade has a garlic-like odor.).

- Extremely flammable; dangerous fire risk; burns with intensely hot flame.

- LEL = 2.5% volume in air. UEL = 82-100% volume in air.

- Autoignition Temperature = 581 F (305 C)
  - NIOSH ceiling = 2500 ppm (2662 mg/m^3).
    (NIOSH 1997)

- Common contaminants: hydrogen sulfide, phosphine and arsine.

- Forms explosive acetylide compounds with silver, mercury, copper, and brasses (containing > 66% Cu) which should be excluded from contact with acetylene in transmission systems. Piping used should be electrically bonded and grounded.

- The use of cast iron fittings is not permissible.

- Acetylene in its free state, under pressure, may decompose violently. The higher the pressure, the smaller the initial force required to cause an explosion. Therefore, never use the free gas outside the cylinder at pressures in excess of 15 psig.

- Acetylene acts as an asphyxiant by diluting the oxygen in the air to a level which will not support life. However, prior to reaching a level where suffocation could occur, the lower explosive (flammable) limit will have been reached and this, of course, constitutes a more serious hazard.

- When using acetylene, close the cylinder valve before shutting off the regulator, to permit the gas to bleed from the regulator.

- Acetylene cylinders should be used or stored only in an upright position to avoid the possibility of acetone leaking from the cylinder. (Acetylene is shipped dissolved in acetone).

- Never store reserve stocks of acetylene cylinders with reserve stocks of cylinders containing oxygen. They should be separately grouped.

- When using acetylene, good ventilation should always be provided to remove any explosive mixture as rapidly as possible.

- It is preferable that acetylene be stored in an upright position; however, where this is impossible, it is recommended that the cylinder be put in an upright position and left that way for about a half hour before being used.

- Care should be taken to see that acetylene cylinders are located as far as possible from falling molten metal and slag. Torches should be directed away from the area of the cylinder.

10.2 AMMONIA (NH_3)

- First complex gas to be identified in interstellar space.

- TLV 25 ppm (18 mg/m^3). STEL = 35 ppm (27 mg/m^3) IDLH = 300 ppm.
(ACGIH 2000; & NIOSH 1997 – all)

- LEL = 15%. UEL = 28%.

- Autoignition Temp (in iron) = 1204 F (651 C)

- Autoignition Temp (in quartz) = 1562 F (850 C)

- Odor threshold = 50-53 ppm (irritating odor detectable at 0.04 to 50 ppm).

- Combustible gas.

- Explodes when mixed with chlorine and heated, due to the formation of extremely sensitive nitrogen trichloride (a toxic gas). Excess chlorine without heat will react similarly.

- Forms explosive compounds in contact with silver or mercury.

- Incompatible with strong oxidizers, acids, halogens, salts of silver and zinc. (Note: Corrosive to copper & galvanized surfaces.)

- Colorless gas with strong, pungent, irritating, suffocating odor.

- Although ammonia does not meet the DOT definition of a flammable gas (for labeling purposes), it should be treated as one.

10.3 ARSENIC (As) & ARSENIC OXIDES (AsOx)

- Arsenic is a nonmetallic element of atomic number 33, group VA of the periodic table.

- TLV = 10 µg/m3 of air

- Poison, carcinogen, mutagen

- mp=814 C - sublimes at 613 C

- Silver-gray, brittle, crystalline; darkens in moist air

- Reacts with nitric acid

- Low thermal conductivity; a semiconductor

- Insoluble in water, soluble in most alcohols

- Used to make gallium arsenide for dipoles and other semiconductor devices

- Doping agent in germanium and silicon solid-state products.

- Reacts with acid to form a highly toxic gas, arsine (see listing this section).

- Hydrogen gas can react with inorganic arsenic to form the highly toxic gas, arsine (see listing this section).

10.4 ARSINE (AsH_3)

- Colorless gas with a garlic-like smell.

- TLV = 0.05 ppm. (0.2 mg/m^3)* *(ACGIH 2000 / OSHA)* STEL Ceiling = 0.0005 ppm (0.002 mg/m^3) *(NIOSH 1997)*

IDLH = 3 ppm**
(NIOSH 1997)

* Listed on ACGIH Notice of Intended Proposed Limit for 2001 = 0.002 ppm (0.006 mg/m^3).
** IDLH was 6 ppm in 1990.

As can be seen by the above variances the toxicity of this very dangerous compound is still being assessed by the various agencies. As with all the dangerous compound in MDL, we attempt to maintain levels below detectable limits in our operations.

- LEL = 5.1% UEL = 78%

- Odor threshold = <1.0 ppm typical, (0.5 to 4 ppm)

- Class A poison

- Highly soluble in alcohol.

- Incompatible with strong oxidizers, chlorine, nitric acid.

- Target organs: blood, kidney, liver.

- Hemolysis occurs requiring immediate medical intervention.

- The EPA Level of Concern = 0.3 ppm. This is the maximum concentration of gas in air that will not cause serious health effects in the majority of the population when exposed to the gas for a relatively short period of time.
- Exposure to 6-15 ppm is dangerous after 30 minutes. 25-50 ppm may be lethal after 30 minute exposure. 10 ppm may be lethal after long exposure. 250 ppm may be instantly fatal. The mortality rate for 120 cases from 1959 to 1998 was 32%.

- Symptoms from arsine exposure can be delayed from 2 to 24 hours after exposure. Abdominal pain and hematuria (i.e. blood in the urine) are cardinal features of arsine poisoning and are frequently accompanied by jaundice (i.e. yellowing of the skin). Severe headache, malaise, weakness, dizziness, giddiness, dyspnea (i.e. shortness of breath) with abdominal pain, pain in the kidneys and liver, nausea, vomiting, and diarrhea are also signs of delayed arsine exposure.

10.5 BORON TRICHLORIDE (BCl_3)

- Colorless fuming liquid.

- Corrosive gas.

- Decomposed by alcohol and by water.

- Strong irritant to tissue.

- Fumes are corrosive and toxic.

- TLV = 1 ppm (recommended) TLV-ceiling = 5 ppm (recommended)
(No TLV or ceilings have been established. Recommended levels shown per manufacturer.)

- Liberates hydrochloric acid (see listing this section) and boric acid when in contact with water or moist air. This appears as a white cloud.

- Pump operations involving chlorine and boron trichloride may produce phosgene (See listing this section). Perfluorinated polyether fluid (Fomblin Oil) is not recommended for systems using BCl_3 as a process gas since it is suspected of causing the fluid to break down (See Appendix 15– element 4.10).

10.6 BROMINE SOLUTIONS

- Dark, reddish-brown fuming liquid with suffocating, irritating fumes.

- Soluble in common organic solvents, very slightly soluble in water.

- Toxic by ingestion and inhalation.

- TLV = 0.1 ppm (0.7 mg/m^3) *(NIOSH 1997, OSHA, ACGIH 2000)* STEL = 0.2 ppm (1.3 mg/m^3) *(ACGIH 2000)* IDLH = 3 ppm *(NIOSH 1997)*

- Odor Threshold = <0.0099 - 0.46 ppm

- Strong oxidizing agent.

- Attacks most metals; aluminum reacts vigorously and potassium explosively.

- May ignite combustible materials on contact; not combustible by itself.

- Nonmetallic halogen element of group VIIA of the periodic table.

10.7 CARBON MONOXIDE (CO)

- Colorless, odorless, flammable, toxic gas.

- TLV = 35 ppm (40 mg/m3) *(NIOSH 1997 – all)* STEL = 200 ppm (229 mg/m3) IDLH = 1200 ppm

- LEL = 12.5% UEL = 74%

- A dangerous fire hazard when exposed to flame. Severe explosion hazard when exposed to heat or flame. Reacts with sodium or potassium to form explosive products sensitive to shock, heat, or contact with water.

- Carbon monoxide is a chemical asphyxiant, and acts toxically by combining with the hemoglobin of the red blood cells to form the stable compound carbon monoxide-hemoglobin. It thus prevents the hemoglobin from taking up oxygen, thereby depriving the body of the oxygen needed for metabolic respiration.

- The affinity of carbon monoxide for hemoglobin is about 300 times the affinity of oxygen for hemoglobin. After being removed from exposure, the half-life of its elimination from the blood is one hour.

- Inhalations of concentrations as low as 0.04% will result in headache and discomfort within 2 to 3 hours. Inhalation of a 0.4% concentration in air proves fatal in less than 1 hour.

- Lacking odor and color, carbon monoxide gives no warning of its presence, and inhalation of heavy concentrations can cause sudden, unexpected collapse.

- Acute cases of poisoning resulting from brief exposures to high concentrations seldom result in any permanent disability if recovery takes place. Chronic exposure effects can occur at lower concentrations.

10.8 CHLORINE (Cl_2)

- Greenish yellow gas with a strong, pungent, irritating odor.

- Reacts explosively or forms explosive compounds with many common substances such as acetylene, ether, turpentine, ammonia, fuel gas, hydrogen, and finely divided metals. Violent reaction with alcohols.

- Nonflammable gas, but is a strong oxidizer.

- Combines with moisture to liberate O_2 and forms HCl (See listing this section).

- TLV=0.5 ppm (1.5 mg/m^3) STEL = 0.5 ppm (1.5 mg/m^3) IDLH= 10 ppm
(NIOSH 1997 – all)

- TLV=0.5 ppm (1.5 mg/m^3) STEL = 1 ppm (2.9 mg/m^3)
(ACGIH 2000 & OSHA)

- Odor Threshold = 0.03 to 0.4 ppm

- Can be highly irritating to skin, eyes, and lungs. Mild mucous membrane irritation can occur at 0.2 to 16 ppm; eye irritation occurs at 7 to 8 ppm; throat irritation at 15 ppm; and cough at 30 ppm. Very high concentrations can cause fluid in the lungs. Exposures at 50 ppm are dangerous for even short periods. Exposures to 1000 ppm may be fatal, even when the exposure is brief.

- Because of its intensely irritating properties, severe industrial exposure seldom occurs, as the worker is forced to leave the exposure area before being seriously affected.

10.9 DIBORANE (B_2H_6)

- Extremely flammable colorless gas.

- Sickly sweet, repulsive "burnt chocolate" odor.

- Highly toxic.

- TLV=0.I ppm (0.1 mg/m^3) IDLH= 15 ppm
(ACGIH 2000, NIOSH 1997, OSHA)

- LEL = 0.8% UEL = 88% Autoignition Temperature = 100- 125 F (38 -52 C)

- Odor threshold = 1.8-3.5 ppm

- Reacts violently with oxidizing materials, including chlorine.

- Incompatible with water, halogenated compounds, aluminum, lithium, oxidized surfaces, and acids.

- Pure diborane is insensitive to mechanical shock; however, shock and thermally sensitive mixtures may be formed in the presence of impurities such as oxygen, water, halogenated hydrocarbons, etc.

- Decomposes in water to form hydrogen and boric acid.

- Pyrophoric. Diborane ignites spontaneously upon contact with air above 100 F and with moist air at room temperature.

- Dissipates very slowly; may remain in air at STP for several days.

- Can be irritating to eyes, nose, and lungs. Can cause headache, light-headedness, nausea, tightness in chest, and fluid in lungs. May cause changes in the central nervous system. Can be toxic at concentrations below the odor threshold.

10.10 DICHLORSILANE (SiH_2Cl_2)

- Extremely flammable, corrosive gas at STP. Solidified residue is shock sensitive and can spark/ignite upon contact.

- Pyrophoric. It ignites spontaneously in air. Confined mixtures with air are spontaneously explosive.

- LEL = 4.1% in air UEL = 98.8% in air

- Autoignition Temperature > 212 F (100 C), but accumulated monochlorosilane above bulk liquid may reduce this to 136 F (58 C).

- Rapidly reacts with water to form HCl (see listing this section), silical and silicon oxyhydride. Fumes in presence of moisture.

- Can be very irritating and cause severe chemical burns on contact with eyes, skin, mucous membranes, and lungs. Symptoms can be delayed.

- Fire Extinguishers are ineffective in controlling fires and gas leaks; the gas supply must be turned off.

10.11 DIMETHYL ZINC (DMZ)

- Molecular formula: $(CH_3)_2Zn$

- Pyrophoric; air and moisture sensitive

- Incompatible with: air, water, oxidizers, and organic halides

- Thermal decomposition or combustion may result in CO, CO_2 and toxic oxides of zinc.

- Contact with water will evolve flammable methane gas and zinc hydroxide.

10.12 ETHYLENE (C_2H_4)

- A colorless, flammable gas with a sweet and musty odor.

- No TLV or ceiling values established.

- LEL = 2.7 % UEL = 36 %

- A very dangerous fire hazard when exposed to heat or flame.

- A simple asphyxiant.

- Ethylene is nontoxic and has been used as an anesthetic, but has been replaced in anesthesia in the United States and Canada due to its flammability.

- No deleterious action by ethylene on circulatory, respiratory, or other systems or organs has been observed. Exhalation eliminates the major portion of ethylene within minutes, although complete desaturation from body fat takes several hours.

- Prolonged inhalation of substantial concentrations result in unconsciousness. Light and moderate anesthesia is attained, and deep anesthesia seldom occurs. Inhalation is fatal only if the gas acts as a simple asphyxiant, depriving the body of necessary oxygen.

10.13 FLUORINE (F_2)

- Nonmetallic halogen. Pale-yellow to greenish gas with a pungent, irritating odor.

- Most electronegative element and powerful oxidizing agent known.

- Most reactive member of the periodic table.

- Reacts vigorously with most oxidizable substances at room temperature, frequently with ignition.

- Forms fluorides with all elements except helium, neon, and argon. Reacts with water to form hydrofluoric acid (see listing this section).

- Dangerous fire and explosive risk.

- TLV = 0.1 ppm (0.2 mg/m^3) *(ACGIH 2000, NIOSH 1997, OSHA)* STEL = 2 ppm (3.2 mg/m^3) *(ACGIH 2000)* IDLH = 25 ppm *(NIOSH 1997)*

- Odor threshold = 0.1-0.2 ppm

- Very strong irritant to tissue, direct exposure will cause burns in 0.2 second.

- Nonflammable gas, but an extremely strong oxidizer.

- Small leaks may be detected using ammonia vapor expelled at suspected points of leakage from a squeeze bottle of concentrated ammonium hydroxide solution (which forms dense white fumes in the presence of fluorine) or with filter paper impregnated with potassium iodide solution (which will turn from light brown to black and will detect levels down to about 25 ppm). In using the filter paper method, hold the paper with metal tongs or forceps about 18 to 24 inches (46 to 61 cm) long.

10.14 HYDROGEN (H_2)

- Nonmetallic element of atomic number 1, group IA of the periodic table. Colorless, odorless, tasteless gas at STP.

- Highly flammable and explosive.

- LEL = 4.1% in air UEL = 74.2% in air Varies somewhat with pressure, temperature, and water vapor content.

- Autoignition temperature = 752 F (400 C)

- The minimum energy of combustion of hydrogen is very low: 0.017 millijoules, which is at least ten times lower than that for hydrocarbons (e.g. 0.28 millijoules for methane, 0.25 millijoules for propane, etc.).

- Hydrogen exhibits stoichiometric combustion with:
    - flame temperature = 1430 C
    - maximum flame speed = 2.65 m/s.

- Practically no toxicity except that it may be an asphyxiate.

- Rate of permeation through solids is approximately four times that of air.

- Can exist in crystalline form at 1 atm. at 14 K.

- Utilized as a reducing atmosphere for preventing oxidation.

- Flammable or explosive when mixed with air, oxygen, or chlorine. Hydrogen burns in air with a pale blue, almost invisible flame. To fight fire, stop flow of gas.

10.15 HYDROGEN CHLORIDE (HCl)

LIQUID:
- Corrosive (acid)

- Can cause burns to skin and eyes. Repeated or prolonged exposure to dilute solutions can cause skin rash.

ANHYDROUS GAS:
- Colorless to slightly yellow fuming gas with a sharp, pungent, irritating, suffocating odor.

- TLV-ceiling = 5 ppm (7 mg/m^3) *(ACGIH 2000, NIOSH 1997, OSHA)* IDLH = 50 ppm *(NIOSH 1997)*

- Odor threshold = 0.255-10.06 ppm

- Strong irritant to eyes, skin, mucous membranes, and lungs. 35 ppm causes irritation of the throat. The maximum concentration that can be tolerated for several hours is 10 to 50 ppm. The maximum concentration that can be tolerated for 60 minutes is in the range of 50 to 100 ppm. Exposures to concentrations of 1300 to 2000 ppm for a few minutes can cause death. Repeated exposure of the skin to concentrated anhydrous hydrogen chloride vapor may result in burns or dermatitis.

- Nonflammable, corrosive gas.

- Soluble in water, alcohol, and ether.

- Incompatible and highly corrosive with most metals. Adsorption of the acid onto silicon dioxide is exothermic.

- Small leaks may be found with an open bottle of concentrated ammonium hydroxide solution (which forms dense white fumes in the presence of hydrogen chloride) or with wet blue litmus paper (which is turned pink by hydrogen chloride).

10.16 HYDROGEN FLUORIDE (HYDROFLUORIC ACID (HF))

LIQUID:
- Clear, colorless, fuming, corrosive (acidic) liquid.

- Must not be stored in glass or metal containers. Use polyethylene containers.

- Can cause severe burns to skin and eyes. Skin and eye contact may not be immediately evident; pain may not start for up to 24 hours.

ANHYDROUS GAS:
- Colorless nonflammable gas with a strong irritating odor.

- Very soluble in water.

- TLV = 3 ppm (2.5 mg/m^3) *(NIOSH 1997, OSHA* - STEL Ceiling = 6 ppm (5 mg/m^3) *(NIOSH 1997* IDLH = 30 ppm *(NIOSH 1997)*

STEL Ceiling = 3 ppm (2.5 mg/m^3)
(ACGIH 2000)

- Odor threshold = 0.04 ppm

- Leaks will appear as white fumes or vapors of hydrofluoric acid which is very acidic and dangerous.

- Toxic by inhalation and ingestion. Exposure to 2.6 to 4.8 ppm for long periods of time may cause slight irritation of the nose, eyes, and skin. Higher concentrations can cause chemical burns to skin, eyes, and lungs. Concentrations of 50 to 250 ppm are dangerous even for brief exposures.

- Strong irritant to mucus membranes and skin.

- Will attack glass and any silicon-containing material.

- Unlike other acids, HF burns penetrate the skin, causing destruction of deep tissue layer including bone (i.e., HF attacks calcium in the body). This process may continue for days.
Note: Effects of overexposure may not be noticeable for some time (up to several hours). All exposures should be considered extremely serious and treated by a qualified physician.

10.17 HYDROGEN SELENIDE (H_2Se)

- Colorless gas soluble in water.

- Highly toxic gas with a disagreeable odor resembling decayed horse radish.

- TLV = 0.05 ppm (0.16 mg/m^3) IDLH = 1 ppm
(ACGIH 2000, NIOSH 1997, OSHA)

- Odor threshold = 0.3 ppm (but rapid reduced sensitivity due to olfactory fatigue)

- Dangerous fire and explosion risk.

- Reacts violently with oxidizing materials.

- Toxic by inhalation. Exposure to less than 0.2 ppm can cause nausea, vomiting, metallic taste, bad breath, weakness, and fatigue. Exposure to 1.5 ppm can cause eye and nose irritation.

- Very poisonous, strong irritant to skin, eyes, and mucous membranes. Causes central nervous system effects in humans.

- Damaging to lungs and liver.

10.18 HYDROGEN SULFIDE (H_2S)

- Colorless gas.

- Offensive "rotten egg" odor.

- Soluble in water and alcohol.

- Highly flammable; dangerous fire risk.

- TWA (TLV) = 10 ppm (14 mg/m^3) *(ACGIH 2000)*

STEL = 15 ppm (21 mg/m^3) *(ACGIH 2000)*

STEL-10 min = 10 ppm (14 mg/m^3) *(NIOSH 1997)*

IDLH = 100 ppm *(NIOSH 1997)*

STEL = 20 ppm with 50 ppm (10-min max peak) *(OSHA)*

- TWA (TLV) may be reduced to 5 ppm in 2001 by the ACGIH.

- LEL= 4.0% UEL = 46% Autoignition Temperature = 500 F (260 C)

- Odor Threshold = 0.001 - 0.13 ppm

- Target organs: respiratory system and eyes. Exposure to 50 ppm for a long period of time can cause severe irritation and damage. Exposure to 1000 ppm can cause death immediately. Note: Although the olfactory senses detect very low levels of H_2S, continuous exposure leads to rapid olfactory fatigue.

10.19 METHANE(CH_4)

- The first member of the paraffin (alkane) hydrocarbon series. It is the major constituent of natural gas.

- Colorless, tasteless, odorless flammable gas

- Flash point = -306 F (-188 C) Boiling point = -258.7 F (-161.5 C)

- LEL = 5% UEL = 15% Autoignition temperature = 1202 F (650 C)

- A simple asphyxiant. Very dangerous fire and explosion hazard when exposed to heat or flame.

- Reacts violently with powerful oxidizers. Reacts with bromine and chlorine in light (explosively in direct sunlight).

- Important products by steam cracking or partial oxidation are methanol, acetylene, hydrogen cyanide, and ammonia.

- Chlorination gives carbon tetrachloride, chloroform, methylene chloride, and methyl chloride.

10.20 NITROUS OXIDE (N_2O)

- Synonyms: Nitrogen Oxide; Dinitrogen monoxide; Hyponitrous acid anhydride; Laughing Gas.

- Colorless, nonflammable gas with a slightly sweet odor and taste.

- Nonflammable gas. An oxidizer. It does not burn, but is flammable by chemical reaction and supports combustion at elevated temperatures.

- It can form an explosive mixture with air.

- TLV = 50 ppm (90 mg/m^3) *(ACGIH 2000)* TWA (TLV) = 25 ppm (46 mg/m^3) *(NIOSH 1997)*

- Prolonged exposure may cause numbness, tingling, weakness, and blood cell damage.

- Nitrous oxide's primary physiological effect is central nervous system depression. Nitrous oxide abuse can cause death by reducing the oxygen necessary to support life. It can impair an individual's ability to make and implement life-sustaining decisions.

- Suspected of causing reproductive disorders.

10.21 OXYGEN(O_2)

- Nonmetallic gaseous element.

- Colorless, odorless, tasteless diatomic gas.

- Constitutes 20.95% by volume of air at sea level.

- Oxygen's outstanding properties are its ability to sustain animal life and to support combustion. It is required by the body for combustion in the tissues in amounts proportional to energy expenditures.

- When pure oxygen is breathed for 5 hours at sea level, or for shorter periods at elevated pressures, signs and symptoms of toxicity will appear. These include nausea, dizziness, bronchial irritation, hypothermia, increased depth of respiration, bradycardia (slow heart action), pulmonary discomfort or injury, peripheral vasoconstriction, amblyopia or loss of vision, syncope (fainting), epileptic seizures , and death. Mixtures of up to 65% oxygen in air may be inhaled for extended periods with no known ill effects.

- The normal 21% of oxygen in the air produces a partial pressure of about 160 torr at sea level. If the oxygen partial pressure is reduced to 120 torr, impairment of mental performance is soon detectable. Although there is considerable variation among individuals in their sensitivity to hypoxia and the effects may vary depending upon activity, some consensus as to the observable symptoms to atmospheres deficient in oxygen exist. If oxygen levels fall to 12-16% by volume, breathing and pulse rate increase and muscular coordination is slightly disturbed. At oxygen levels of 10-14%, consciousness continues, but there are emotional upsets, abnormal fatigue upon exertion, and disturbed respiration. At oxygen levels of 6-10%, there is often nausea and vomiting and an inability to move freely. Loss of consciousness may occur, and some may collapse and although aware of circumstances, be unable to move or cry out. Below 6%, convulsive movements and gasping respiration is observed. Respiration stops and a few minutes later heart action ceases. (Refer to Section 16.6.7.2 for oxygen deficiency monitoring levels in MDL.)

- Nonflammable, but is essential to combustion. Extreme oxidizer. It can ignite organic materials spontaneously upon contact.

- Since Oxygen will liquefy (Boiling point = -297 F = -182 C = 91 K) at temperatures above the temperature of liquid nitrogen (-320 F = -196 C = 77 K), caution should be exercised when exposing liquid nitrogen traps to air and particulates (e.g. flaking thin film deposits, etc.) or alcohols or combustible materials. Liquid oxygen is a transparent, pale blue liquid that is slightly heavier than water. (See also cautionary note Section 11.5.)

- Must be plumbed in materials specifically cleaned for oxygen use.

- Oxygen under pressure will rapidly oxidize oil or grease, resulting in an explosion.

- Equipment specifically cleaned for oxygen service must be used. Oily fittings should never be used with oxygen.

10.22 OZONE(O_3)

- Colorless to blue gas with a very pungent odor.

-PEL = 0.1 ppm (0.2 mg/m^3) *(OSHA)* STEL ceiling = 0.1 ppm (0.2 mg/m^3) *(ACGIH 2000, NIOSH 1997)* IDLH = 5 ppm *(NIOSH 1997)*

- Odor Threshold = 0.008 to 0.04 ppm

- A human poison by inhalation.

- Toxic at low concentrations. A skin, eye, upper respiratory system, and mucous membrane irritant. Exposure to 0.05 to 0.1 ppm for 13 to 30 minutes causes irritation and dryness of the throat. Above 0.1 ppm, coughing, choking, chest pain, difficulty in breathing and blurred vision can occur. More severe exposures can also cause headache, dizziness, and a burning sensation in the eyes. Exposure to 0.6 to 0.8 ppm for 2 hours can result in difficulty in breathing for up to 24 hours.

- Severe explosion hazard in liquid form when shocked or exposed to heat or flame, or in concentrated form by chemical reaction with powerful reducing agents.

- Nonflammable gas, but a powerful oxidizer.

- Incompatible with all oxidizable materials (both organic and inorganic) including rubber.

10.23 PHOSGENE ($COCL_2$) - (By-product of certain operations--e.g. pump operations involving chlorine)

- Synonyms: carbonyl chloride; carbon oxychloride; carbonyl dichloride; chloroformyl chloride.

- At STP phosgene is a colorless, nonflammable gas with a suffocating odor like that of sour green corn or musty hay.

- Phosgene under pressure (1.6 atm) liquefies to a light yellow liquid.

- Highly poisonous.

- TLV = 0.1 ppm (0.40 mg/m^3) *(ACGIH 2000, NIOSH 1997, OSHA)* STEL ceiling = 0.2 ppm (0.8 mg/m^3) *(NIOSH 1997)* IDLH 2 ppm *(NIOSH 1997)*

- Odor threshold 0.5 ppm

- Phosgene vapors strongly irritate the eyes. It is also a strong lung irritant and will attack other parts of the respiratory system. Exposure to 3 to 5 ppm will result in cough, eye and throat irritation within 1 minute. Exposure to 10 ppm will result in irritation of the eyes and respiratory tract in less than 1 minute. Exposure to 20 ppm by volume will result in severe lung injury within 1 to 2 minutes. Exposure to 50 to 90 ppm will be rapidly fatal (30 minutes or less).

- Serious symptoms may not develop until several hours after exposure. The immediate symptoms produced by even a fatal dose may be relatively mild since phosgene elicits no marked respiratory reflexes. Thus, a person who appears to be mildly gassed immediately after exposure may become a casualty several hours later. The delayed action of phosgene can be particularly injurious if the victim performs heavy exercise after having been exposed.

- Most pronounced symptoms are coughing with bloody sputum and weakness lasting for several months.

- Reacts slowly in water to form hydrochloric acid (see listing this section) and carbon dioxide.

- In the presence of moisture, phosgene is not compatible with copper, steel, or pure or cast iron.

10.24 PHOSPHINE (PH_3)

- Colorless, flammable gas that is heavier than air.

- Disagreeable fishy or garlic-like odor. (Pure compound is odorless.)

- Soluble in alcohol, ether, and cuprous chloride solution. It is a strong reducing agent.

- TLV = 0.3 ppm (0.42 mg/m^3) *(ACGIH 2000, NIOSH 1997, OSHA)* STEL = 1ppm (1.4 mg/m^3) *(ACGIH 2000, NIOSH 1997)* IDLH = 50 ppm *(NIOSH 1997)*

- LEL = 1.79 % UEL = ? (Unknown) Autoignition Temperature = 100 F (37.8 C)

- Odor threshold = 0.01 to 5 ppm

- Highly toxic by inhalation.

- Strong irritant to eyes, nose, lungs. Exposures averaging under 10 ppm can cause headache, breathing difficulties, chest tightness, cough, loss of appetite, abdominal pain, giddiness, numbness, lethargy, nausea, vomiting, and diarrhea.

- Spontaneously flammable. High concentrations (>15%) are pyrophoric.

- Fire extinguishers are ineffective in controlling fires from gas leaks; the gas supply must be turned off.

- Phosphine will react violently with oxidizers such as oxygen, chlorine, fluorine, and nitric oxide.

- Report all suspected exposures immediately.

10.25 PHOTORESISTS

- Hazards are associated with or result from volatile ingredients:
    - 2-ethoxyethyl acetate: kidney damage, narcosis, paralysis, fetal deaths, birth defects, male infertility.
    - Xylene: readily absorbed through the skin; eye, skin, and mucous membrane irritant; causes corneal vacuolation, dermatitis, reproductive effects, and birth defects.
    - n-butyl acetate: suspected of causing teratogenic effects and birth defects.

- Major entry route is by absorption and not inhalation.

- Silver shield gloves under natural rubber gloves offer the best protection for the combination of photoresist and acetone while still allowing adequate manual dexterity.

- In 1992, IBM warned its workers and other companies that diethylene glycol dimethyl ether and ethylene glycol monoethyl ether acetate (EGMEA) may increase the risk of miscarriage. This was based on a study it commissioned by John Hopkins University who found that among 30 women who worked with the chemicals and then became pregnant, 10 had miscarriages. The link between diethylene glycol dimethyl ether and ethylene glycol monoethyl ether acetate (EGMEA) to reproductive effects in humans has not been proven to date. Alternative photoresist chemistries to eliminate EGMEA-based photoresists have been introduced. In particular photoresists containing Propylene Glycol Monomethyl Ether Acetate (PGMEA) seem to be effective and less toxic.

- A review of the photoresist hazards within MDL was presented at a user meeting on 11/30/1999 and the detailed information presented may be accessed at http://mdlwww.jpl.nasa.gov/support/user meetings/1999-11-30/photoresist safety.html. It was decided that all EGMEA-based photoresists will be removed in MDL and future purchases shall not be allowed.

10.26 SILANE (SiH_4)

- Synonyms: silicon tetrahydride, monosilane, silicane

- Colorless, flammable gas with repulsive, choking odor-at STP.

- Pyrophoric; spontaneously flammable in air.

- TLV = 5 ppm (6.6 mg/m^3)
(ACGIH 2000, NIOSH 1997 OSHA – none)

- LEL = 1.3 % UEL = ? (Unknown)

- Odor Threshold = 0.5 ppm

- Silane reacts with water to form silicic acid and can therefore cause irritation of the eyes, mucous membranes, and respiratory tract. Inhalation of unreacted silane in air can cause headache and nausea. Acute effects may be similar to arsine (see listing this section), but it is far less toxic. May react to form silica dust (TLV= 3 to 10 mg/m^3) which when inhaled may cause silicosis.

- Store at positive pressures.

- Piping and equipment should be thoroughly pressure checked above working pressure and verified to be leak tight.

- Do not condense silane by avoiding temperatures of -148 F (-100 C) or less.

- Evacuate, purge with inert gas, and evacuate again before introducing silane into piping and systems. Always open valving slowly when introducing silane.

- Be very cautious about using silane in systems with halogenated compounds. Even a trace of free halogen can be violently explosive with silane.

- Mixtures down to 1.0% silane in hydrogen and/or nitrogen have been found to be spontaneously flammable when mixed with air. At very high escape velocities, mixtures as high as 10% may spontaneously ignite. High concentrations of silane are not always pyrophoric immediately, but may explode if the gas release continues. Slow leaks of silane into non-ventilated areas may form a bubble which may explode through ignition at the interface.

- Ground all lines and equipment used with silane.

10.27 TCE – TRICHLOROETHYLENE (C_2HCl_3)

- Stable, low-boiling, colorless, photoreactive liquid with a chloroform-like odor.

- Will not attack the common metals, even in the presence of air.

- Accumulated data (and analysis by the ACGIH Chemical Substances TLV Committee, 1995-1996) indicates TCE is not suspected as a human carcinogen. (TCE was once a suspected carcinogen.) Nevertheless, NIOSH -1997 considers TCE to be a potential occupational carcinogen and recommends a 10 hr TWA (TLV) = 25 ppm. If utilized as an anesthetic agent then NIOSH recommends an REL (recommended exposure limit) of 2 ppm as a 60-minute ceiling.

- TLV in air = 25 ppm (134 mg/m^3) *(ACGIH 2000* STEL = 100 ppm (537 mg/m^3) *(ACGIH 2000)* IDLH = 1000 ppm *(NIOSH 1997)*

- PEL (TLV) in air = 100 ppm (537 mg/m^3) *(OSHA)* STEL = 200 ppm (1074 mg/m^3) with a 300 ppm 5-min max peak in any 2 hrs *(OSHA)*

- LEL = 8 % to 12.5% UEL = 10.5% at 77 F(25 C); UEL = 90% at > 86 F (>30 C)
Autoignition Temperature = 788 F (420 C)

- Odor Threshold = 0.5 to 167 ppm in air.

- Flash Point = 89.6 F (32 C), but practically nonflammable. (i.e., The liquid is combustible, but it burns with difficulty.) Vapors can be moderately flammable at high temperatures.

- Can cause eye irritation. Repeated contact can cause skin irritation.

- Vapors can cause headache, dizziness, sleepiness, and irritability. Exposure to 1000 ppm for 2 hours can cause visual and coordination problems. Repeated exposures may cause liver and kidney damage.

SECTION 11

COMPRESSED GAS CYLINDER AND CRYOGENIC DEWAR SAFETY

A compressed gas is any material in a container exhibiting an absolute pressure of 40 psia at 20 C (68 F) or in excess of 104 psia at 54.5 C (130 F), or a liquid having a vapor pressure exceeding 40 psia at 100 F (37.8 C). (40 psi absolute = 25.3 psig).

11.1 COMMON HAZARDS

11.1.1 A low boiling point, which results in:
- rapid diffusion and pressure buildup.
- frostbite in contact with body tissues.

11.1.2 A low flash point: A flash point below room temperature allows an explosive mixture with air to form rapidly.

11.1.3 High pressure can lead to several problems, such as leakage due to faulty pressure control or valve seals.

11.1.4 Damage to the neck or body of the cylinder can result in explosive decompression, causing the cylinder to act like an unguided missile.

11.1.5 Diffusivity: Diffusion through leaking valve seats or fittings may cause rapid contamination of the ambient room air, in turn causing the rapid formation of explosive mixtures, toxic effects, and asphyxiation.

11.1.6 All hazards are compounded when one considers that, in many cases. there will be no visual, audible, or olfactory warning.

11.2 SAFETY DEVICES

11.2.1 The Department of Transportation (DOT) provides specifications against which cylinders must be built and performance tested.

11.2.2 Cylinders containing nontoxic, noncorrosive, flammable or inert gases have bursting discs to prevent explosion in the event of fire.

11.2.3 Cylinders containing highly toxic materials do not have a bursting disc. This may also be true for other toxic and corrosive materials. In addition, cylinders with some flammable materials may have a bursting disc backed by a fusible plug.

11.2.4 Hazardous gases (flammable, corrosive, poisonous, pyrophoric) are equipped with left-handed threads.

11.2.5 Hazardous gas cylinders shall be plumbed from an approved gas cylinder cabinet adhering to the requirements stated in the Uniform Fire Code, Article 80, and equipped at a minimum with the following safety features:

- continuous gas leak detection
- purge manifold
- excess flow shutoff
- self-closing doors

Exceptions: Plumbing requirement exceptions will be made on an individual basis for flammable gases such as hydrogen when plumbed from outside.

11.3 RECEIVING

11.3.1 Cylinders should always be inspected for the following points:

- DOT label.
- Last date of hydrostatic testing. (See note below.)
- Labeling properly identifying contents.
- Cylinder valve and valve threads for any sign of damage prior to connecting the cylinder.

Note that DOT regulations prescribe hydrostatic retesting every five or ten years. The longer interval, which is allowed for cylinders meeting the conditions specified in 49 CFR 173.34(e)(15), is indicated by a five-pointed star stamped after the last test date on the cylinder shoulder.

11.3.2 Cylinder must be received in good condition. No corrosion or rust should be observed around the neck and valve areas.

11.3.3 If any of the above points are deficient, return the cylinder to JPL Gas & Cryogenics.

11.4 STORAGE

11.4.1 Cylinders should be stored in an upright position and secured at high and low points using an approved securing device attached to a wall or suitable structure.

11.4.2 Do not store cylinders in heavy traffic areas.

11.4.3 Store gases supporting combustion (e.g., O_2, $C1_2$) separate from fuel gases (20 feet, fire wall, or gas cabinet).

11.5 PERSONAL PROTECTIVE EQUIPMENT (PPE) FOR CRYOGENIC OPERATIONS

Note: Liquid nitrogen left in a container open to the atmosphere will absorb or condense other room gases into it. This liquid nitrogen/liquid air mixture is much more likely to burn skin tissue on contact than liquid nitrogen alone.

11.5.1 Cryogenic operations utilizing more than 1 gallon of liquefied nitrogen or utilizing any quantity of any other liquefied gas will require as a minimum:

- Eye protection (Goggles recommended)
- Face shield
- Appropriate gloves (cryo gloves)
- Apron (cryo apron)
- Monitoring at all times for filling and dispensing operations.

11.5.2 Cryogenic operations utilizing less than 1 gallon of liquefied nitrogen will require as a minimum:

- Cryogenic gloves
- Eye protection (Goggles and face shield recommended)

11.6 HANDLING

11.6.1 Always use a hand truck for transport. Chain cylinder to hand truck.

11.6.2 Do not drop cylinders or permit cylinders to strike each other.

11.6.3 Leave cap on cylinder until secured and ready for use.

11.6.4 Ground all cylinders containing flammable gases.

11.6.5 Use cylinders only in an upright position.

11.6.6 All valves shall be closed when not actually in use.

11.6.7 Use the proper regulator with the appropriate CGA fitting for the particular gas. Always use the proper wrench to fasten the regulator to the cylinder.

11.6.8 Before a cylinder valve is opened, the regulator must be closed or completely backed off. Cylinder valves shall be opened slowly. Avoid backseating cylinder valves. Backseating of cylinder valves is a bad practice for three reasons:

1) It can damage packing material allowing leaks;
2) In the specific case of cylinders with corrosive gases, it can allow corrosive gases to interact with the valving and potentially seal valves in an open position; and
3) It can prevent operators from immediately recognizing whether a cylinder valve is open or shut by "feel".

11.6.9 Never use a wrench to open or close a cylinder valve. If the cylinder valve cannot be opened or closed by hand, contact the MDL Safety Engineer (see Appendix 11).

11.6.10 Always consider cylinders to be full and handle accordingly.

11.6.11 Discontinue using a high-pressure cylinder when the pressure approaches 200 psig, and clearly mark the cylinder EMPTY, then contact the MDL Facilities Engineer (see Appendix 11) for removal and return to vendor.

11.7 GENERAL

11.7.1 Adapters that permit cross servicing of incompatible gases should never be used.

11.7.2 Oxygen under pressure will rapidly oxidize oil or grease, resulting in an explosion. Equipment specifically cleaned for oxygen service must be used. Oily fittings should never be used with oxygen.

11.7.3. Acetylene under pressure can decompose with explosive force. It can explode with extreme violence if ignited. Copper or brass (with more than 60% copper) can form explosive compounds in contact with acetylene.

11.7.4. A regulator leak can build pressure in a closed system. A pressure relief device or a high delivery pressure shutoff device should be included. The cylinder valve shall be closed and valve cap shall be in place whenever possible.

11.8 SPECIFIC TOXIC GAS BOTTLE DELIVERY PROCEDURES

11.8.1 Specific procedures have been developed for toxic gas bottle deliveries to MDL's Hazardous Gas Bunker, 302-154. They may be accessed electronically at http://mdlwww.jpl.nasa.gov/facility/HazardousGasBunker/deliveries.html.

11.9 SPECIFIC HYDROGEN DELIVERY PROCEDURES TO HYDROGEN BUNKER

11.9.1 Two sets of hydrogen 6-PAKs are utilized in the Hydrogen Gas Bunker, 302-155, in the east equipment pad area of building 302. They provide the hydrogen source gas needs to the MOCVD fabrication area, 302-153. Delivery, hook-up, and disconnect procedures for this operation are detailed at:
http://mdlwww.jpl.nasa.gov/facility/H2bunker/hydrogen.html.

GAS DELIVERY CHECK LIST
MDL GAS BUNKER PROCEDURES
(Rev. 2001.03, dated 6/29/2001)

GAS TYPE		**REQUESTOR**	
VENDOR		**DATE**	
PR / PO#		**CERTIFICATE#**	

1. GAS ORDER CHECK LIST (for person placing order)
   a. Begin a Gas Delivery Checklist record sheet for gas order.
   b. Request individual cylinder certificate.
   c. Request flow restriction orifice (if required).
   d. Define bottle change procedure to vendor.
   e. Notify MDL Safety Engineer and verify with her (him) that proper gas detection equipment is functional.

2. DELIVERY NOTIFICATION CHECK LIST
   a. Vendor provides advance notice of gas delivery (four days advance notice desired) to person placing order who notifies MDL Safety Engineer and Gas Handlers.
   b. Vendor specifies whether or not the truck is equipped with a cylinder lift gate and is open or enclosed (if known).
   c. MDL Safety Engineer informs JPL Security, Fire department, Cryogenics and OSO and EAO.
   d. Gas Handlers purge pigtail connection and cap cylinder to be returned prior to delivery.

3. TRUCK ARRIVAL AT JPL CHECK LIST
   a. Truck checks in at south guard gate and waits for security escort at parking area in front of Bldg 202. (Note that if an enclosed truck, it should NOT be opened at this point.)
   b. Guard informs JPL Emergency Console Operator who notifies JPL Cryogenics, Fire Department, Security, OSO, EAO, and the Emergency Response Administrator.

4. TRUCK IS ESCORTED BY SECURITY TO MDL.
   a. Truck parks adjacent to MDL Gas Bunker (typically to the east).
   b. Driver sets parking brake and chocks wheels if conditions (slope, equipment, or toxicity) warrant it as determined by the MDL Safety Engineer or designated alternate (i.e. Designated Safety Officer for the operation).
   c. JPL Security (Plant Protection) barricades pedestrian, and automotive routes in the immediate vicinity of the Gas Bunker, and parking area at the south-east and south-west sides of MDL.
   d. MDL Safety Engineer (or designated alternate) fully instructs driver of procedures.

e. If the delivery truck is not equipped with a cylinder lift and conditions (e.g. size of cylinder, etc.) warrant it as determined by the MDL Gas Handler or Safety Officer, a JPL Cryogenics or Transportation forklift equipped with a cylinder skid will meet the delivery truck at MDL and perform all loading and unloading of cylinders from the delivery truck.
f. MDL Safety Engineer checks and verifies that Gas Handlers are in communication with each other and the MDL Safety Engineer.
g. MDL Safety Engineer verifies she (he) is in communication with JPL Plant Protection (i.e. Zebra Control).
h. Gas Handlers unlock and open Gas Bunker doors.

5. TRUCK AIR MONITORING FOR ENCLOSED CARGO COMPARTMENTS.
   a. Gas Handlers don air supply equipment and verify breathing and communication units are functional.
   b. MDL Safety Engineer and driver move to a safe distance, at least ten paces up wind.
   c. Gas Handlers verify truck is secure (i.e. parking brake set and, if required, wheels are chocked).
   d. Gas Handlers crack open truck door enough for gas monitor sample line to be inserted (approx. 1/4 inch).
      i. Condition 1 – Leak found:
         1. Gas Handlers immediately shut door.
         2. Gas Handlers inform MDL Safety Engineer.
         3. MDL Safety Engineer informs JPL Fire Incident Commander on scene and halts delivery procedure.
         4. Fire Incident Commander informs the JPL Emergency Console, Security, Fire Department, OSO, and EAO.
         5. MDL Safety Engineer evacuates driver and herself (or himself) to a safe area.
         6. Gas Handlers evacuate area.
         7. Emergency shall be handled according to the JPL Multi-Hazard Response Plan and the JPL Safety Manual.
      ii. Condition 2 – No leak found:
         1. Proceed to steps 6 and 7.

6. USED CYLINDER RETURN CHECK LIST
   a. Gas Handlers verify that supplied air units and communication equipment are functioning properly.
   b. Gas Handlers inspect used cylinder through gas cabinet access window.
   c. Gas Handlers verify that cylinder valves are tightly shut.
   d. Gas Handlers verify that CGA blank-off cap is secured tightly (if present).
   e. Gas Handlers securely fasten cylinder cap.
   f. Gas Handlers remove cylinder from gas cabinet.
   g. Gas Handlers secure cylinder to gas cylinder hand truck. (Exception: Very small cylinders may be hand carried.)

h. Gas Handlers inspect cylinder for leaks using portable leak detection instrument.
    i. Condition 1 – Leak found:
        1. Gas Handlers place cylinder into gas cylinder cabinet, secure and close cabinet door.
        2. Gas Handlers inform MDL Safety Engineer.
        3. Gas Handlers repeat steps 2 through 5 in "Used Cylinder Return Check List".
        4. If a leak is still detected, Gas Handlers place cylinder into leaky cylinder cabinet.
        5. Gas Handlers inform MDL Safety Engineer. MDL Safety Engineer informs JPL Fire Incident Commander on scene, gas delivery driver and halts delivery procedure.
        6. Fire Incident Commander informs the JPL Emergency Console, Security, Fire Department, OSO and EAO.
        7. Emergency shall be handled according to the JPL Multi-Hazard Response Plan, and the JPL Safety Manual.
    ii. Condition 2 – No leak is found:
        1. Gas Handlers return used cylinder in gas cylinder hand truck to driver. (Exception: Very small cylinders may be hand carried.)
        2. Driver secures used cylinder to truck.

7. NEW CYLINDER UNLOADING CHECK LIST
    a. Driver verifies that cylinder cap is securely fastened.
    b. Driver secures cylinder to cylinder hand truck. (Exception: Very small cylinders may be hand carried.)
    c. Driver lowers cylinder from truck (or transfers cylinder to MDL Gas Handlers) and moves to safe area with MDL Safety Engineer.
    d. Gas Handlers verify that the cylinder cap is securely fastened.

8. NEW CYLINDER INSPECTION CHECK LIST
    a. Gas Handlers monitor cylinder for gas leak at valve, collar and cap area.
        i. Condition 1 – Leak is found:
            1. Gas Handlers place cylinder into leaky cylinder cabinet. If leaky cylinder cabinet is occupied, place cylinder into corresponding cabinet.
            2. Gas Handlers inform MDL Safety Engineer.
            3. MDL Safety Engineer informs JPL Fire Incident Commander on scene and halts delivery procedure.
            4. Fire Incident Commander informs the JPL Emergency Console, Security, Fire Department, OSO and EAO.
            5. Emergency shall be handled according to the JPL Multi-Hazard Response Plan, and the JPL Safety Manual.
        ii. Condition 2 – No leak found:
            1. Proceed to next step.

b. Gas Handlers inspect cylinder for proper labeling and tags.
    i. Condition 1 -- Cylinder fails labeling and tag inspection:
        1. Gas Handlers return cylinder to driver and inform MDL Safety Engineer.
        2. MDL Safety Engineer informs JPL Security, Fire Department, OSO, and EAO.
        3. Driver loads cylinder onto truck.
        4. Driver secures cylinder to truck.
    ii. Condition 2 -- Cylinder passes inspection:
        1. Proceed to next step.
c. Gas Handlers install cylinder in corresponding gas cabinet check list.
    i. Gas Handlers transport cylinder in hand truck into gas bunker.
    ii. Gas Handlers secure (chain) cylinder into gas cabinet.
    iii. Gas Handlers close gas cabinet door.
    iv. MDL Safety Engineer and/or Gas Handlers update appropriate inventory records.
    v. If more than one cylinder is to be delivered, repeat steps 6 through 9 on additional check lists (one per cylinder).

9. GAS DELIVERY END PROCEDURE
    a. Gas Handlers close and lock gas bunker doors.
    b. Safety Engineer informs JPL Security that gas delivery is complete.
    c. Safety Engineer releases driver and pedestrian and automotive traffic is allowed to resume.
    d. Gas Delivery Checklist is completed and archived by the custodian of record, the MDL Safety Engineer.

signed_____ date_____

print name_____

Send Updates to the MDLWWW webmaster.

GAS DELIVERY CHECKLIST, MDL GAS BUNKER PROCEDURES
Document Owner: James L. Lamb
Custodian of Record: Keith Fields
Review Cycle: 24 months
Next Review due before: June 29, 2003
"Gas Cylinder Delivery Check List" records will be kept for one year by their custodian of record, the MDL Safety Engineer. Disposed records will be shredded and recycled.

CHANGE HISTORY:

Effective Date: June 29, 2001
Revision Number: 2001.03
Description: This is a revised document. Revisions include minor corrections and formatting changes. "MDL" and "PROCEDURES" were added to the title. The Document Owner, Custodian of Record, Review Cycle, Next Review due before, and Change History were explicitly added. A revision number was assigned. The designator OSEH was updated to JPL OSO and JPL EAO. The 4 day vendor advance notification time in step 2 was modified as desired instead of required. Trucks are to park adjacent to the Gas Bunker (typically to the east) instead of to the west of the Gas Bunker. The requirement to chock wheels and need for a forklift was reduced to an option if conditions warrant it as assessed by the MDL Safety Engineer or designated alternate. "Gas can" in step 6 was corrected to read "gas cylinder hand truck". "Activation of gas bunker emergency mushroom buttons" was removed as a procedure in the event of leaks in steps 5, 6, and 8. Record control information has also been added.

Hydrogen Bunker Procedure

Revised 07/03/01

UTILIZE NON-SPARKING TOOLS ONLY

Hydrogen 6-Pak Removal

Close the HPI valve and the 6-pac manifold valve. Close all the 6-pak cylinder valves. Open the HPV valve to exhaust the pressure in the pigtail. Close the HPV valve and disconnect the pigtail CGA from the 6-pak.

Remove the ground cable from the building ***first***, then remove the cable from the 6-pak. Unchain the 6-pak, remove the chocks from the wheels and then move the 6-pak to the reserve position.

Hydrogen 6-Pak Installation

Position the 6-pak adjacent to control panel, secure by chocking wheels and chaining the 6-pak to the bunker wall. Hook up the ground cable by connecting to the 6-pak ***first*** then to the building ground.

Check that the 6-pac manifold valve is closed.

Check that both the HPV valve and the HPI valve are CLOSED. Connect the panel pigtail to the 6-pak. Open one cylinder valve and ***slowly*** open the 6-pak manifold valve. Leak check the GGA fitting on the pigtail by using snoop or equivalent. If a leak is found attempt to repair the leak. If the leak persists contact the gas and cryogenics for a replacement 6-pak.

Open the five remaining cylinder valves an snoop the individual cylinder CGA's and the stem seals for leaks. If a leak is found attempt to correct the leak. If the leak persists, contact Gas and Cryrogenics for a replacement 6-pak.

Open and close the HPV valve **twice rapidly** to purge the air in the pigtail. Now slowly open the HPI valve and verify that the regulator reads approx. 150 psig.

Locate the control box located the outside wall on the southeast corner of bldg 302, to right of the hydrogen bunker. Open the waterproof door and press the horn reset button. Then press the service ready button A or B depending on which 6-pak you changed. Log appropriate data concerning the installation in the log book.

SECTION 12

ELECTRICAL SAFETY AND LOCKOUT POLICY

12.1 SCOPE

This section covers MDL requirements and responsibilities for the installation, use, and maintenance of electrical equipment with sustained voltage of not more than 600 volts between conductors. Any work involving sustained voltages greater than 600 volts requires additional training and authorization from JPL OSO.

12.2 RESPONSIBILITIES

As a general rule, Facilities Engineering is responsible for the electrical distribution system up to the point of use. Individual machines and instruments are the responsibility of the cognizant Section Manager, Group Supervisor, and Engineer.

12.2.1 The Section Manager has the responsibility to see that all areas under his or her cognizance are safeguarded against electrical hazards and that the requirements of this policy section are fully implemented.

12.2.2 It is the responsibility of each Group Supervisor to see that:

- All point-of-use devices are of UL approved type in compliance with the National Electrical Code.
- All employees working with or around energized electrical equipment are instructed on the hazards involved and how to protect themselves from such hazards.
- All aspects of this policy section are practiced and enforced.
- Electrical devices used in the area are regularly inspected. Defective devices shall be removed from service.
- Safe access or work clearance is maintained around all electrical panels, switches, and controllers in compliance with the NEC.

12.2.3 It is the responsibility of the MDL Safety Engineer to assist the Section Manager and Group Supervisors in complying with this section and, together with the JPL OSO, act as a resource in the interpretation of Subpart S of the Code of Federal Regulations, the National Safety Code, and all applicable state and JPL requirements.

12.3 DEFINITIONS

12.3.1 LOCKOUT TAGS. All lockout tags have a danger warning sign on top and a place to mark the name of the person who installed it. There are various types of lockout tags available for use in MDL:

- Equipment Locked Out
- Men Working On Machinery
- Do Not Operate

- Do Not Start
- Out Of Order

- These tags should be used only when inadvertent operation of the equipment may pose a hazard to personnel or cause property damage.

- Positive methods, such as barriers or locks, shall be used in conjunction with these tags when the potential for serious injury or property damage is present.

- The tags and locks are to be removed upon completion of the work, only by the person(s) who installed them. If removal is required and the person who installed them is unavailable, supervision should be contacted (see Section 12.4.12).

- These tags are available from the MDL Safety Engineer or the MDL Safety Technicians. There are also Lockout Tag stations mounted in the equipment room (302-236) and in the Chemical Transport Corridor (302-145).

12.3.2 LOCK. A lock is a fastening device employing keys, used at control points such as valves, switches, or moving parts on machinery or equipment where a fixed state is required to protect personnel performing the work. Locks may be obtained through the MDL Safety Engineer.

12.4 LOCKOUT / TAGOUT PROCEDURE

Further information and JPL official policy statements concerning lockout / tagout procedures may be found in the JPL DMIE system (e.g. Lockout/Tagout/Blockout Policy).

12.4.1 Before starting work, the person performing the service shall pull or turn the main switch to the off position, insert the lockout device, insert a padlock, and lock it out.

12.4.2 If a switch cannot be locked out because of damage, it must be repaired so that a lock may be used, or power must be locked out on the upstream side of the circuit.

12.4.3 Close and bleed out all air, steam, and hydraulic lines when applicable to work to be performed.

12.4.4 Press all control buttons to make sure that power is off.

12.4.5 Block any load or machine part before working under it.

12.4.6 Each employee working on the equipment must have his personal padlock on the deactivated circuit breaker or disconnect

12.4.7 Lockout tags shall always be used in conjunction with the lock and shall be removed upon completion of the work at the time the lock is removed.

12.4.8 The lockout tag shall have the employee's name, date, and work to be performed.

12.4.9 No employee shall ever permit someone else to remove his lockout tag and padlock unless an emergency is present and procedures as described in part 12.4.12 of this section are followed.

12.4.10 When tags must remain on control points for an extended period of time or are exposed to weather elements, plastic tags with wire fasteners or card tags in plastic covers with wire fasteners shall be used.

12.4.11 A circuit breaker or disconnect shall be activated only when each employee has personally removed his own padlock and lockout tag and the area has been inspected to insure that no employee will be endangered by the activation.

12.4.12 In an emergency, when the person who attached the lock and tag is not available, the lock and tag may be removed by the supervisor in charge, after all precautions have been taken to assure that no hazards exist. If this is done, all concerned shall be notified as soon as possible.

12.4.13 If a key is lost, the lock shall be rekeyed or replaced.

12.5 ELECTRICAL SAFETY

12.5.1 Under no circumstances shall tape be used to secure a breaker in either the on or the off position. Proper securing devices are available through the MDL Safety Engineer.

12.5.2 Under no circumstances shall a circuit breaker panel door be locked unless all breakers contained inside are in the off position.

12.5.3 Always assume that all circuits are energized during inspection.

12.5.4 Never grasp electrical equipment as the equipment may be energized and cause involuntary clamping of the hand to the energized parts. Instead, it is recommended that workers approach the equipment and make initial contact back-handed.

12.5.5 Use only one hand when with or near energized electrical equipment.

12.5.6 Do not work in wet areas. Avoid handling electrical equipment when wet.

12.5.7 Always use lockout procedures.

12.5.8 During periodic inspections check for:
- Wire color coding, connections and insulation defects

- Grounding
- Proper insulation
- Condition and availability of safety equipment
- Openings in electrical enclosures
- Improper installations
- Improper identification
- Unguarded energized parts
- Suitable access around electrical equipment

12.5.9 Extension cords are for temporary use only and are not to be used in place of permanent wiring. They shall be UL listed and heavy enough for anticipated loads and used singly, never extension to extension.

12.5.10 Suitable temporary barriers or barricades shall be installed when access to open enclosures containing exposed energized electrical equipment is not under the immediate control of an authorized person.

12.5.11 Conductive measuring tapes, ropes, ladders, or similar devices shall not be used near energized conductors or parts of equipment.

12.5.12 Persons working on energized circuits should avoid wearing metallic rings, watches, or bracelets. Nonmetallic watches and rings should also be avoided because they have a tendency to catch on equipment.

12.5.13 Products designed for home use, regardless of the UL label, which are not grounded and have exposed non-current-carrying metal pans shall not be brought into the work place. Retrofitting is not recommended.

12.5.14 Products such as refrigerators, coffee or hot water dispensers, and microwave ovens must comply with JPL's General Fire Safety Requirement, Doc. # 45352 found on JPL's DMIE system. Some applications may require a permit issued by the JPL Fire Department. Contact the Section Safety Coordinator / MDL Safety Engineer for further information.

SECTION 13

LASER SAFETY

The JPL Laser Safety Program is defined in the JPL DMIE requirement document DMIE-45393. It has been established to ensure that lasers are used safely and in compliance with applicable rules and regulations. It is applicable to all JPL employees, contractors, and other personnel engaged in, or who are visiting, activities using lasers at JPL, including MDL laboratories.

13.1 GENERAL

13.1.1 All procurement requisitions for lasers must be reviewed and approved by the MDL Safety Engineer and the JPL Occupational Safety Office (OSO) through the JPL Laser Safety Officer (LSO).

13.1.2 The Laboratory has adopted the standards contained in ANSI Z136.1 (American National Standards Institute). Any required deviation from this standard shall be approved by the JPL OSO.

13.1.3 JPL's " Laser Hazards and Operations Safety Manual", Doc. # 1516 and JPL's "Laser Safety Program" DMIE Requirement Document, Doc. # DMIE-45393 found on JPL's DMIE system define the requirements necessary to operate a laser at JPL. Laser use requires the following:

13.1.3.1 Prior to switching on any laser the cognizant supervisor or manager shall ensure that an Operational Safety Review (OSR) package is prepared.

13.1.3.2 The OSR package shall include the following documentation:

13.1.3.2.1 A completed Pre-OSR, JPL Form 0284 (See Sec. 4.17).

13.1.3.2.2 A completed Laser Safety Data form -- Attachment A in document DMIE-45393.

13.1.3.2.3 A completed PPE Assessment form.

13.1.3.2.4 A completed PPE Training Certification form.

13.1.3.2.5 A completed "Medical Surveillance Request Form" (JPL 2633-S) (See Sec. 4.20), or proof that the relevant employees have already received laser eye examinations.

13.1.3.2.6 Proof that the employee working with the laser or laser system has received appropriate training.

13.1.3.2.7 A Standard Operating Procedure (SOP) for all Class 3B and Class 4 lasers or laser systems as shown in Attachment B in document DMIE-45393.

13.1.3.3 The Pre-OSR form and the Laser Safety Data Sheet must receive the appropriate signatures after which the entire package is forwarded to JPL's OSO and JPL's LSO for final review.

13.1.3.4 The JPL LSO reviews the document, completes a Laser Hazard Assessment for all Class IIIB and Class IV LASERs and signs the Pre-OSR along with all Laser Safety Data Sheets.

13.1.3.5 The JPL OSO will distribute copies of the approved OSR package.

13.1.3.6 The JPL OSO will coordinate any medical examinations that might be required for the use of PPE with the occupational health section.

13.1.3.7 The JPL OSO will distribute the approved Pre-OSR to the requesting organization.

13.1.4 Employees who deal with lasers require periodic training as defined in Section 6.4.2.1.1 and the JPL DMIE requirement document DMIE-45393.

13.2 LASER CLASSIFICATIONS

The following is a summary of power and energy levels used to establish laser classes.

	CLASS I	II	III	IV
CW	10^{-5} W/cm^2	10^{-3} W/cm^2	0.5 W/cm^2	greater than 0.5 W/cm^2
PULSED	10^{-6} J/ cm^2	-	less than 10 J/cm^2	greater than 10 J/cm^2
Q SWITCH	10^{-7} J/cm^2	-	less than 10 J/cm^2	greater than 10 J/cm^2

13.3 LASER SAFETY POLICIES

13.3.1 Eye protection appropriate for the power and frequency of the laser light must be worn when working with or near a class III or IV laser.

13.3.2 A laser warning sign must be posted on or about the area where lasers are in use.

13.3.3 An operating laser must never be left unattended unless it is positioned in a posted and locked enclosure.

13.3.4 The laser and all optical instruments used for the beam must be stable and secured.

13.3.5 Beam-absorbent materials should be placed around the beam path and as a back stop.

13.3.6 The laser beam path must be free of reflective and shiny objects that are not directly employed for shaping or positioning the beam.

13.3.7 A special ophthalmologic examination shall be performed whenever an exposure occurs and an eye injury is suspected.

13.3.8 Keys must be removed from laser power supply key switches when in the "off" position. Otherwise, a violation of the lockout / tagout standards exists.

13.3.9 Class III and IV laser beams must be confined to the immediate area required for the purpose of the laser work. Wherever possible, the laser beam should be completely enclosed; otherwise, the room or immediate area shall be sealed off so as not to allow the laser beam to escape the area. All such areas shall be considered controlled areas.

13.3.10 Class III and IV lasers require posting of lighted hazard warning signs in and at all entrances to the area of laser operation.

13.3.11 Class III and IV lasers require interlocks so as to stop the light beam in the event the controlled area (room, curtained area, or beam enclosure) is opened while the laser is active.

13.4 LASER WARNING LABELS

13.4.1 Lasers fabricated and packaged by MDL taskwork shall at a minimum, meet the labeling requirements detailed in ANSI Z136.1-2000. Labels shall include the laser hazard symbol, the appropriate warning phrase, the type of laser (e.g. Nd:YAG, Helium-Neon, etc.), the emitted wavelength, pulse duration (if appropriate), the maximum output (Watts or Joules), and the class of laser or laser system.

13.4.2 A copy of ANSI Z136.1-2000 is available from the MDL Safety Engineer.

SECTION 14

MACHINE SHOP SAFETY

The majority of the MDL machine shop equipment from the MDL machine shop, 302-149, has been relocated in January, 2001, to the Tech. Shop in bldg. 103 under the cognizance of Section 357. The original MDL machine shop, 302-149, has been closed and the space converted into laboratory use. Functionality and access for MDL Users has been retained through a resident Sec. 357 Machine Shop Operator in the bldg. 103 Tech. Shop who is directed to provide priority support to MDL Users. All users of JPL machine shops bear the responsibility of following appropriate safety practices as dictated in the documents specified in Section 14.1 and as directed by the cognizant machine shop coordinators.

14.1 APPLICABLE DOCUMENTS

- California Code of Regulations, Title 8.

- Laboratory Safety Manual under Doc. I.D. # 1537, "Machine, Tool, and Equipment Safety, SPI 4-08-97".

- Material Safety Data Sheets (MSDS) [covering materials utilized in machining operations].

14.2 RESPONSIBILITIES

14.2.1 Line Management

JPL line management is responsible for the implementation of proper safety practices within JPL, including the JPL Machine Shop and Tech. Shop areas. This includes ensuring that personnel using the JPL Machine Shops and Tech. Shops have been appropriately trained to ensure safe accomplishment of assigned tasks.

14.2.2 MDL Shop Coordinator / Cognizant Engineer

Although the ultimate authority to define JPL Machine Shop implementation practices and procedures now lies under the cognizance of Section 357 management, the following responsibilities are defined and expected for the Shop Coordinator / Cognizant Engineer assigned to interface with and support MDL Users in the bldg. 103 Tech. Shop. It is the responsibility of the MDL Shop Coordinator / Cognizant Engineer to oversee operations for MDL Machine Shop Users for the benefit and safety of all concerned. This includes:

- Maintaining safe practices
- Restricting the use of equipment to qualified personnel
- Maintaining the records of authorized machine shop users (See Section 4.21)
- Prohibiting or stopping any unsafe practice
- Prohibiting or stopping any practice or operation that is not good shop practice or is harmful to the equipment
- Maintaining shop equipment

14.2.3 Section Safety Coordinators
Section Safety Coordinators (Sec. 384 & Sec. 357) shall examine procedures and oversee the Machine Shop safety effort on an ongoing basis. The Section Safety Coordinators also have the responsibility of prohibiting or stopping any unsafe practice.

14.2.4 Machine Shop Users
Safety is the responsibility of all employees using the JPL Machine Shops and Tech. Shops. All activities must be in compliance with safety policies and must be performed in a manner that promotes personnel safety and safe operation of tools and equipment.

14.3 SAFETY RULES

14.3.1 Access and Authorization

14.3.1.1 Any person desiring to directly use machine shop equipment in the bldg. 103 Tech. Shop under the functional umbrella of an MDL authorized user must have authorization from his/her Group Supervisor, the MDL Manager, his/her Section Manager, and the MDL Machine Shop Coordinator / Cognizant Engineer, prior to using the Machine Shop equipment (Request for Direct Use of Machine Shop Equipment as an Authorized MDL User Form 1736 R 1/01--see Appendix 18). After hour key access to the area and equipment may also be requested on this form and may be granted if relevant management and the Cognizant Shop Coordinator concurs. (Use of the Buddy System is required.)

14.3.1.2 Employees are permitted to use shop equipment only with appropriate training as determined by the Shop Coordinator/Cognizant Engineer.

14.3.2 General Safety Rules

14.3.2.1 The buddy system (two people within contact of each other or an electronic pendant alarm system with proper notification) is required at all times while operating power tools in the JPL Machine Shops.

14.3.2.2 Personnel are not permitted to leave equipment operating unattended.

14.3.2.3 No one shall distract the attention of persons operating power equipment. Scuffling, horseplay, and practical jokes within the environs of the machine shop are dangerous and will not be tolerated.

14.3.2.4 After hours access is limited to authorized personnel only. (See form in Appendix 18).

14.3.2.5 Radios, tape players, and miniature TV sets requiring the use of head-phones are forbidden when operating equipment.

14.3.2.6 Smoking is prohibited in the JPL Machine Shops and Tech. Shops.

14.3.2.7 Hair longer than shoulder length must be tied in back when operating machinery.

14.3.2.8 Machine shop users are responsible for leaving the shop in a clean and orderly state.

14.3.3 Personal Protective Equipment (PPE) Requirements

14.3.3.1 A face shield and eye protection shall be worn for grinding operations. Observers shall also wear eye and face protection.

14.3.3.2 Impact-resistant safety goggles or safety glasses shall be worn when operating any metal working equipment or tools. Observers are also required to wear eye protection.

14.3.3.3 Personnel whose primary function involves machining operations are required to wear safety shoes. Safety shoes are available through the JPL OSO. Personnel who use the Machine Shop on an irregular part-time basis are not required to wear safety shoes; however, sandals and open-toed shoes are not to be worn in the Machine Shops and Tech. Shops.

14.3.3.4 Ear protection is required when the noise level is above acceptable decibel levels (>85 dB).

14.3.3.5 Equipment operators shall not wear jewelry, neckties, or other loose clothing when operating power equipment.

14.3.4 Special Precautions and Requirements

14.3.4.1 Air hoses shall be regulated to not more than 30 psig and OSHA-approved diffusing nozzles shall be installed.

14.3.4.2 Machine Shop users shall review Material Safety Data Sheets (MSDSs) to familiarize themselves with the hazards associated with the use of solvents, cutting fluids, and materials to be machined prior to performing any work.

14.3.4.3 Oily or greasy rags shall be placed in labeled, closed metal containers and shall be disposed of on a daily basis. For disposal, contact JPL's EAO. Waste containers should be labeled "Flammable Waste - Dispose of Daily."

14.3.4.4 When small quantities of oil or solvent are leaked or spilled on the floor, they shall be cleaned up immediately with absorbent materials. Contaminated absorbent material should be placed in a labeled, closed metal can. Large spills should be reported to the JPL Fire Department.

14.3.4.5 Machine Shop operators should know the location of fire extinguishers and how to use them. The JPL Fire Department will provide training in the proper use of fire extinguishers.

14.3.4.6 Magnesium machining operations require a Pre-Operational Safety Review and a type D fire extinguisher, and they shall comply with NFPA 480. When working with magnesium, an excessive amount of chips shall not be allowed to accumulate. Residual chips shall be placed in a labeled, closed metal container. This is to be disposed of as hazardous waste. All hazardous waste disposal is to be coordinated with JPL's EAO.

14.3.5 Power-driven Equipment

14.3.5.1 Defective tools or equipment shall be reported immediately to the Shop Coordinator/Cognizant Engineer.

14.3.5.2 Cutting tools must be visually inspected, and dull cutting tools must be resharpened prior to use.

14.3.5.3 Operators shall remove all wrenches and chuck keys from chucks immediately after using them.

14.3.5.4 All materials to be drilled or turned shall be clamped securely before starting a machine. Only properly sharpened drills and cutting tools shall be used.

14.3.5.5 Operators shall not start any power-driven equipment until the safety guards are properly in place and in working order. Safety guards may be removed only to make necessary adjustments or repairs and must be replaced before the equipment is placed back into operation.

14.3.5.6 Operators shall not reach or lean over moving cutters. rollers, chucks, or other moving machine parts.

14.3.5.7 Operators shall run machinery only at correct speed, and not exert excess force or feed too fast; broken drills and blades can result in serious injury.

14.3.5.8 Loose materials, such as rags, shall not be used around moving parts.

14.3.5.9 Operators shall shut machine power off before cleaning, adjusting, gauging parts, oiling machine, making changes in setup, making electrical adjustments or removing stuck or jammed pieces of material.

14.3.5.10 Operators shall never attempt to stop a machine by grabbing the chuck or by using any part of the body as a brake.

14.3.5.11 Operators shall never use their hands to remove chips or materials from machine parts; a brush, stick or other appropriate tool shall be used.

14.3.5.12 When using a grinder, the operator shall always grind on the face of the wheel, never on the sides. Do not use grinders for soft metal or plastics; use the belt or disc sander.

14.3.5.13 All electrically operated machinery shall comply with the National Electrical Code (NEC).

SECTION 15

CLEANROOM POLICIES

15.1 ACCESS AND USER CLASSIFICATIONS

15.1.1 All personnel authorized to enter the cleanroom proper (Class 100-10 / ISO 5-4) envelope are indicated in the "Cleanroom Access List" (Section 4.4) which is maintained electronically within the cardreader data-base at the entrance to the air shower. This list is a subset of the "MDL H-6 Area Access List" (Section 4.15) posted in the lighted bulletin board to the north of the H-6 entrance in the hallway 302-100 and indicates that not only has the appropriate safety training been completed (necessary for H-6 access), but also necessary cleanroom training and orientation has been addressed. Additions to the database may be inputted by members of the Central Processing and MDL Support Group on verification that all requirements for access have been met.

15.1.1.1 MDL User Classifications:

15.1.1.1.1 There are three MDL H-6 User processor status classifications based on direct MDL use and experience:

1) "Trainee / New Hire";
2) "Fully Qualified"; or
3) "Senior".

15.1.1.1.2 "Trainee / New Hires" will be assigned this status upon first accessing the H-6 and/or cleanroom proper areas of MDL. This status indicates that the specified personnel require additional training and they have additional restrictions and oversight requirements which must be followed. (See Sec.15.1.1.2 below.)

15.1.1.1.3 "Fully Qualified" Processors may access the H-6 area unescorted. They are considered to have demonstrated a specific proficiency and knowledge of the H-6 area, protocols, and procedures. This status is achieved by the fulfilling of a number of requirements. (See Sec. 15.1.1.4 below.) Note that personnel may achieve the "Fully Qualified" status for the peripheral Class 100,000 (ISO 8) areas of MDL (i.e., the MBE and MOCVD processing areas), but must transition into the "Trainee / New Hire" status if they subsequently access the cleanroom proper areas and have not yet achieved the "Fully Qualified" status there. Note that processors who have achieved the "Fully Qualified" status for the cleanroom proper (class 100-10, ISO 5-4) areas are considered fully qualified for the entire H-6 area.

15.1.1.1.4 MDL "Senior" Processors are evaluated and assigned this rank by MDL Management from the pool of "Fully Qualified" Processors. This status is achieved by the fulfilling of specific objective requirements and an assessment /review by the other MDL "Senior" Processors and MDL Management (see Sec. 15.1.1.1.4.3 below).

15.1.1.1.4.1 Only MDL "Senior" Processors may act in the role of MDL "Mentors" to train new personnel.

15.1.1.1.4.2 MDL "Senior" Processors are automatically members of the MDL Senior Processors Advisory Committee who reports to and advises MDL Management on MDL policies and procedures. Among its duties, this advisory committee will assess, elect, and provide recommendations to MDL Management for the elevation of "Fully Qualified" candidates to the position of an MDL "Senior" Processor.

15.1.1.1.4.3 "Fully Qualified" Processors may be elevated to the "Senior" Processor status if the following criteria are met:

1) Candidates must have been an MDL "High User" for at least a year [i.e., someone who utilizes the MDL cleanroom proper at a "high" rate (i.e., > 50 hours in a 6 month period)].
2) Candidates must have been present in the MDL Cleanroom for at least 300 hours in any single year period (equivalent to about 6 hours per week for 50 weeks).
3) Candidates must exhibit "exemplary" practices in both safety and operations.
4) Candidates must be intimately familiar with procedures and protocols of the MDL cleanroom / H-6 areas and should be able to not only answer all "Cleanroom Practicals" questions in depth, but also demonstrate to the Senior Processor Advisory Committee members that they can effectively teach and convey this information to others.
5) Candidates must have demonstrated leadership in MDL communal issues (through both participation and communication of good practices, existing policies, and potential improvements to their peers (fellow processors) and MDL management).
6) Candidates must be unanimously elected in a meeting of the Senior Processor Advisory Committee (with the understanding that the candidate list will be distributed to all members of the Senior Processor Advisory Committee in advance so that members who are unable to attend the official meeting may vote in absentia if desired). The election results and recommendations will be forwarded to the MDL Manager.
7) MDL Management has final review and approval authority for "Senior" Processor assignments. Appointments to the "Senior" Processor status will be formally made by MDL Management.

Nominations for advancement to the MDL "Senior" Processor classification should be submitted in writing to the Senior Processor Advisory Committee or to the MDL Manager who will forward the same to the Senior Processor Advisory Committee. Supporting documentation and examples may be requested addressing the above requirements. Candidates may have to submit to a review process by the Senior Processor Advisory Committee.

15.1.1.1.4.4 It is noted that although technical knowledge plays a role in attaining the status of an MDL "Senior" Processor, it is not the primary criteria. Technical knowledge, experience, and job responsibility of an individual is reflected in the level of their JPL job classification (i.e., Associate, Staff, Senior, or Principal). In this instance the MDL designations of "Trainee/New Hire", "Fully Qualified". and "Senior" Processor relate to an individual's familiarity and expertise related to MDL cleanroom day-to-day operations and protocols. They are two separate classifications and distinctions. The MDL "Senior" Processor classification was instituted to ensure that proper orientations and training would be provided by qualified MDL "Mentors".

15.1.1.1.5 There also exists a special MDL "Senior - 100" classification which allows a person to be designated a "senior" processor for a specific, but limited, operation or area for the purposes of allowing that person to train another and "mentor" that person in that specific operation or area. For example, this designation may be applied to MDL H-6 processors who meet all of the criteria for a senior processor, but do not access or work in the MDL cleanroom proper (class 100- 10 / ISO 5 - 4) areas.

15.1.1.2 All new processors (i.e. "Trainees/ New Hires") will be assigned a qualified (See Sec. 15.1.1.1.4.1) cleanroom contact ("Mentor") by the cognizant MDL group supervisor. Candidate "Mentors" must be formally documented on the MDL Authorization Form of the "Trainee/ New Hire" and approved by the MDL Manager, or designated alternate (See MDL Authorization Form & Certification Record, Appendix 5.)

15.1.1.2.1 MDL "Mentors" and their supervisors are responsible for ensuring that all MDL policies and procedures are followed. (See Sec. 3.4.3.) In addition, the MDL "Mentor" is responsible for clearly conveying and training their MDL "Trainees/ New Hires" in the procedures and protocols of the area in question and demonstrating and ensuring good practices (both safety and operational) are followed. All "Cleanroom Practicals" questions (See Sec. 15.1.1.4) should be reviewed with the "Trainee/ New Hire" by the "Mentor".

15.1.1.3 All new processors (i.e., Trainees/ New Hires) will be typically mentored for a period of two to six weeks, depending on their previous training and experience. All work done in the cleanroom by the new processor during this period will be with their mentor who must be available to answer questions and assist as needed. This oversight will continue until the "Trainee / New Hire" transitions to the "Fully Qualified" status.

15.1.1.4 In order to transition to the "Fully Qualified" status, all "Trainees/ New Hires" will be required to pass an oral practical exam (i.e., "Cleanroom Practicals") when their Mentor believes the new processor is ready to work alone. Both the designated Mentor, and MDL Process Leader (or designated alternates – presently another MDL Senior Processor) will conduct the test and assess competency. The transition to "Fully Qualified" status is documented in the MDL Authorization Form (Appendix 5) and is

available electronically. These records are maintained by the MDL Safety Engineer (custodian of record).

15.1.2 Personnel not on the cleanroom access list must obtain written permission and must be instructed in cleanroom procedures prior to entering the cleanrooms (See Sections 3.4, 3.9, and 6.4.)

15.1.3 Personnel entering the cleanroom proper (class 100 - 10 / ISO 5 - 4) must sign in and out on the cleanroom log or utilize the adjacent badge reader located at the entrance to the cleanroom. (See Section 4.5.)

15.1.4 Access to the H-6 cleanroom areas is through the entry hallway 302-144 only, where gowning takes place to access the other class 100,000 (ISO 8) areas. Access to the cleanroom proper (class 100 - 10 / ISO 5 - 4) is through the air shower 302-140 only. Shoes should be cleaned for 10 seconds each prior to entering the air shower or gowning for the class 100,000 (ISO 8) areas.

15.1.5 Personnel with colds or other upper respiratory infections, or afflicted by chronic coughing or sneezing, shall remain outside of the cleanroom area until sufficiently recovered. Examples of physiological problems that are detrimental to cleanroom operations are:

- Allergies to synthetic fibers
- Allergies to solvents used in processing operations
- Profuse nasal discharge
- Skin conditions resulting in greater than normal shedding or flaking of the skin or dandruff
- High acid content of moisture of the hands
- Severe nervous conditions, itching, scratching, or claustrophobia.

15.1.6 Outer clothing coverage required in the cleanrooms will be cleanroom compatible. Street clothes may be worn in only four areas of the H-6 envelope:

1) The entry / transition hallway 302-144,
2) The control room 302-139,
3) The gowning area 302-141, and
4) The chemical preparation area 302-150 (if accessed from the exterior of the building). All other H-6 areas have gowning requirements to protect the environment from the people.

Class 100,000 (ISO 8) areas in the H-6 envelope require shoecovers and smock coats. Face masks, gloves, and bouffant caps are optional, but recommended.

The cleanroom proper (class 100-10 / ISO 5 - 4) areas require that coveralls, boots, gloves, and hoods shall be worn at all times. Face masks are required for personnel with facial hair other than eyebrows, and for any personnel at any time while in the class 10 (ISO 4) rooms.

Prior to entering the cleanroom H-6 areas, it is recommended that you:

- Wash your hands and face.
- Use the shoe cleaner located at the entrance to the cleanroom.
- Check white board for messages. (The board is located at the entrance to the cleanroom.)
- If you smoke:
    - Wait 30 minutes after smoking before entering cleanroom.
    - You are encouraged to imbibe water after smoking and before entering the cleanroom, to reduce the particulates.

15.1.7 The following rules apply to the air shower 302-140, gowning area 302-141, and all H-6 cleanrooms:

- Do not comb or brush hair.
- No smoking, eating, or drinking is permitted in the cleanroom. (Chewing gum and tobacco are not permitted.) [No food or drink is allowed in the H-6 area.]
- Do not wear clothing that produces a great deal of lint.
- Do not wear jewelry with sharp edges: they can cut your cleanroom gloves.
- Do not remove outer cleanroom garments in the cleanroom work areas. Coveralls and/or smock coats are to remain zipped up or buttoned up at all times.

15.1.8 Sequence of gowning for the cleanroom proper (class 100 - 10 / ISO 5 - 4) area is as follows:

- Follow preliminary sequence as outlined in 15.1.6.
- Don the hood and, if required, the face mask. No hair shall show outside of the hood. If required, wear a bouffant cap under the hood to contain the hair. (Face masks are required if you will enter the class 10 (ISO 4) area or if you have facial hair other than eyebrows.)
- Don the coveralls with the collar over the hood bib. If the top portions of the coveralls touch the floor while donning, the coverall must be replaced.
- Don the boots (coverall leggings go inside the boot knee highs). All snaps that secure the boot to the coverall must be fastened
- Don the cleanroom gloves over the coverall sleeve cuffs.

15.1.9 Recommended sequence of gowning for the H-6 class 100,000 (ISO 8) areas is as follows:

- Follow preliminary sequence as outlined in 15.1.6. If desired, don a bouffant cap and face mask. (No hair should show outside of the hair covers.)
- Don the smock coat. Make sure all buttons and snaps are secured.
- Don the shoecovers.
- If desired or if the operation requires it, don cleanroom gloves.

15.1.10 De-gowning is done in the reverse order as the gowning sequence indicated in 15.1.8 and 15.1.9 with one minor modification, if garmenting is to be stored for re-use, then the gloves (presumed clean) should be left on until the last step to minimize contamination of the clean garment surfaces. When de-gowning, shoecovers and garments should be inspected. If they are compromised (i.e., excessively soiled or

degraded) they should either be discarded (if they are disposable or unrepairable), placed in the associated laundry bin (if soiled), or separated into the designated laundry bin for repair (if there is a repairable rip, hole, or missing snaps, etc.).

- Garments stored for re-use should be stored in a manner that minimizes additional contamination of outer clean surfaces. One recommended practice is to store or hang garments inside out so that the clean surface is protected.
- Care should be taken to avoid blocking air return vents in the gowning area 302-141 if garment hooks are utilized.
- In no instance should garments removed from their cleanroom packaging be stored for more than two weeks. They should be re-cycled into the associated bins for laundering.

15.2 MATERIALS AND EQUIPMENT

15.2.1 A set of cleanroom tools shall be cleaned and stored in aisle 302-135. These tools are to stay in the cleanroom at all times. These tools shall be returned at the end of each working day.

15.2.2 Any additional tools required to perform work in the cleanroom must be cleaned with isopropyl alcohol (or isopropyl alcohol / DI water mixture) and protected with approved cleanroom plastic until inside the cleanroom. The plastic may then be removed. Gloves and cleanroom wipes must be used during the cleaning operation.

15.2.3 No wooden rulers, pencils, papers or any other material or device that generates excessive particulates shall be utilized in or brought into the cleanroom envelope. Written materials such as books or manuals may be photocopied onto cleanroom paper or sealed in a clear plastic envelope. Cleanroom pens, paper, notebooks, and other supplies are available through the MDL Support Group.

15.2.4 Prior to using equipment, you must be trained by the Cognizant Engineer or designated trainer. This involves a 3 step process:

1) The Cognizant Engineer or designated trainer demonstrates operation of the equipment while the trainee observes.
2) The trainee operates the equipment under direction of the Cognizant Engineer or designated trainer.
3) The trainee operates the equipment and demonstrates ability to operate the equipment with no help from the Cognizant Engineer or designated trainer or others, while the Cognizant Engineer or designated trainer observes and evaluates.

If all three steps are successfully passed as evaluated by the Cognizant Engineer or designated trainer, then the trainee will be granted full, unsupervised access to the equipment. This authorization will be recorded and may be rescinded at any time at the discretion of the Cognizant Engineer.

15.2.5 To avoid cross-contamination, only materials approved for use on individual equipment may be used. Approved material lists are posted near the equipment. Any deviation must be approved by the Cognizant Engineer and the MDL Manager.

15.2.6 Glassware must be labeled with the user's name and contents of the particular receptacle (see Sec. 9.1.4).

15.2.7 Labware (glass, plastic, syringes, beakers, etc.) must be stored in a poly bin supplied to individual users. Do not store glassware on top of benches or tables.

15.2.8 Report any equipment problems to the MDL Equipment Engineers, MDL Safety Engineer, the MDL Manager, or Cognizant MDL Support Group Members and note them in the appropriate equipment log book. Verbal or written communication methods (hardcopy, e-mail, or MDL electronic newsgroups) are all allowable. (See also Section 15.6.). Users are encouraged to e-mail requests and comments to the entire MDL Support Group for the quickest action.

15.2.9 All equipment and work areas are to be cleaned after use.

15.2.10 Specialized labeling requirements exist for the special circumstance (an exception to standard practices requiring approval by MDL Management) in which MDL researchers (users) desire to retain a specialized chemical beyond its normal expiration date. In this instance, the label must include the following information:

- The words "IN USE"
- The name or names of MDL User Contact people
- The words "SAVE THROUGH" followed by the anticipated end use date (up to 1 year - although extensions may be granted upon review and justification).
- Plus all of the standard information normally required for chemical containers as described in Section 9.1.4.1.

15.3 INSTALLATIONS

15.3.1 Whenever possible, all fabrication shall be accomplished outside the cleanroom.

15.3.2 Any materials brought into the cleanroom must follow cleaning procedure 15.2.2 of this section.

15.3.3 Any holes that must be cut or drilled in the cleanroom walls must have a procedure approved by configuration control prior to the start of any work.

15.3.4 Any operation that could create dust shall be sheltered from other areas of the cleanroom by the erection of polyethylene barriers surrounding the immediate work area before work is started. A HEPA filter equipped vacuum shall be started and suction applied to the work position as required.

15.3.5 After work has been completed, the area shall be vacuumed and wiped down with cleanroom wipes and isopropyl alcohol after the plastic shelter has been removed. A post operation inspection shall be made by a qualified person.

15.4 CLEANROOM MAINTENANCE

15.4.1 The cleanroom maintenance contractor is responsible for maintaining the integrity of the cleanroom.

15.4.2 Upon completion of installation work in the cleanroom, the contractor shall recertify the rooms to the same level as they were prior to the start of work.

15.4.3 JPL contamination control personnel and their equipment may be requested to verify the certification level of each of the cleanroom areas.

15.5 PURCHASING OF CLEANROOM SUPPLIES

15.5.1 Maintenance of the central processing facilities and equipment within MDL includes the purchase of a wide variety of cleanroom supplies and materials. The Central Processing & MDL Support Group, an independent staff of semiconductor processing specialists, is supported to assist in this work and provide processing assistance. Consult with members of this group to see if desired supplies are maintained, ordered, or supported by the group. Requests for proposed additions to cleanroom supplies maintained by the group should be made to the MDL Manager.

15.5.2 Cleanroom supplies and materials of a task specific nature will not be supported through the Central Processing and MDL Support Group.

15.5.3 The MDL Manager and MDL Safety Engineer must be notified and approve of all types of new materials and cleanroom supplies before being brought into the MDL cleanrooms and introduced into operations.

15.6 USER REQUESTS & SERVICES

15.6.1 MDL users are encouraged to make their desires known for improving the quality and safety of operations within MDL. There are a number of parallel processes which may be utilized to submit requests to the MDL Manager or any member of the Central Processing and MDL Support Group:

1) Present the request verbally
2) Discuss the request at the periodically held MDL User meetings
3) Send in a written request (either hard-copy or electronic)
4) Access the MDL newsgroups (see http://mdlwww/newsgroups) or send in e-mails directly through links at the site.

All requests will be discussed, evaluated, and prioritized for action (which may be done on the spot, in weekly group meetings, in other subgroup meetings, or through specially called user meetings).

15.6.2 Equipment problems should be reported following the procedures outlined in Section 15.2.8. Users may view an MDL Equipment "To Do" List under the support heading at the MDL website at http://mdlww. Comments may be made through direct e-mail links at the site.

15.6.3 Direct service help in the areas of device processing, e-beam lithography, material growth, and material and device characterization to enable tasks which will further the goals of NASA may also be requested by both internal and external customers. Access and service charges are defined annually in the "MDL Technical Support Services Holding Account Plan". Interested parties should contact the Provide Microdevices Lab Services Process Owner / MDL Manager for specific details.

15.6.4 Service requests may be requested using the procedure noted in 15.6.1 with specific service work in the areas of e-beam lithography and characterization being routed directly to the Cognizant Engineers for evaluation and acceptance. In addition, the MDL manager may be contacted directly, or through the institutional electronic service request process under Microdevices Lab Services.

SECTION 16

EMERGENCIES

This section defines emergency actions specific to MDL operations. Overriding emergency plans for JPL as a whole are defined in JPL's Multihazard Emergency Response Plan, Doc. # 28012, which may be accessed on JPL's DMIE System.

16.1 NOTIFICATION

16.1.1 FOR ON-LAB EMERGENCIES, DIAL 911 (or 393-3333 if using a cellular phone).

Dialing 911 on lab (or 393-3333 for cellular phones) will put one in contact with the local JPL emergency console. In the event of an emergency, a witness should report as exactly as possible the nature and location of the emergency to the JPL Emergency Console. On-site Emergency Response Personnel are available at JPL.

16.1.2 FOR OFF LAB EMERGENCIES, DIAL 911.

Dialing 911 off-lab will put one in contact with non-JPL emergency operation centers. (Dialing 9-911 on lab will establish the same non-JPL connection).

16.1.3 For emergency assistance from the MDL floor wardens, dial 168 (MDL paging system) and request a floor warden to your location, giving a brief description of the emergency. Wardens are trained in:

- Fire extinguisher use for small fires

- Cardiopulmonary Resuscitation (CPR) and first aid.

Most MDL first floor wardens are also trained in

- Chemical spill control (small spills)

16.1.4 If personnel are not present, abnormal situations will be detected by the MDL life safety and monitoring systems, and annunciated at the JPL Emergency Console. Alarms of a sufficiently high level requiring a building evacuation will automatically link to the MDL Fire Alarm system and initiate a building evacuation. Alternatively, the JPL Emergency Console operators may access the local MDL annunciation system or the JPL global annunciation system to provide verbal information, instructions, and / or directions.

16.1.5 Manual emergency shutoff "panic buttons" (red mushroom buttons) and fire pull stations are placed throughout the H-6 area and by all exits. The activation of any one of these units will result in the immediate shutdown of all hazardous gases and initiate a building evacuation through the MDL fire alarm system. If an evacuation alarm sounds

the building warden or alternate, will contact the JPL Emergency Console (Zebra Control) at 4-3530, or in their absence, any available knowledgeable person will dial 911 (or 393-3333 for cellular phones), to verify the alarm transmission and establish the nature of the alarm.

16.1.6 Personnel are responsible for notifying their supervisor of any emergency, mishap, unusual event, or injury.

16.1.7 The supervisor is responsible for notifying the Section Manager and the Section Safety Coordinator / MDL Safety Engineer. The MDL Safety Engineer will initiate an accident investigation (Section 16.5).

16.2 EMERGENCY CONTACTS

16.2.1 In an emergency, JPL contacts are reached by dialing 911 (alternate 393-3333, if using a cellular phone).

16.2.2 JPL emergency teams and contacts consist of:

- JPL EAO	ph # 4-0180
- JPL Fire Department	ph # 4-3311 business (if no answer dial 4-3530)
- JPL OSO Management Office	ph # 4-4710
- JPL Occupational Health Services	ph # 4-3319
- JPL Security	ph# 4-4160

16.2.3 A complete list of Bldg. 302 wardens is found in Appendix 11.

16.2.4 All equipment requiring specific shutdown procedures or left operating in an unattended state must have the emergency home and work phone numbers of the Cognizant Engineer posted on the equipment.

16.3 EVACUATION

16.3.1 All MDL users are to familiarize themselves with the evacuation routes for each floor of the building and the assembly locations. Maps of the evacuation routes are posted on all floors and appear in Appendix 12.

16.3.2 Emergency evacuation exit doors are to remain closed at all times during normal operations. These doors trigger an alarm and have a detrimental effect on the cleanroom environment when opened.

16.3.3 The utility access corridors 302-145 (north aisle) and 302-152 (south aisle) are used as evacuation routes. Hazardous chemicals may not be transported through or used in these areas at any time unless the cleanroom envelope is first evacuated of all personnel and all entrances are sealed off.

16.3.4 Do not use the elevator at any time during an evacuation.

16.3.5 Follow all instructions from the MDL floor wardens, JPL Security, or JPL Fire Department personnel during any evacuation. All MDL wardens will be wearing orange vests. The floor wardens will be wearing yellow bump caps, and the building warden will be wearing an orange bump cap.

16.3.6 Evacuation drill procedures and warden responsibilities during an evacuation are listed in Appendix 13.

16.3.7 Evacuation chairs are located at each end on the third floor for evacuation of handicapped/disabled personnel.

16.4 RESPONSES TO SPECIFIC INCIDENTS

16.4.1 Hazardous Gas Releases:

- Press the nearest panic button (red mushroom) as soon as you notice the leak. This stops all gases at their source and initiates a building evacuation through the MDL fire alarm system.

- If there is no panic button or other shutoff device immediately available, leave the area at once.

- Notify MDL personnel by either activating a pull station or other initiating device, such as a panic button or use the building intercom system (dial 168). Appendix 14 shows the location of various alarm initiation devices and gas sensors.

- Give a detailed report in all cases to the JPL Emergency Console at ext. 911 (alternate 393-3333 if using a cellular phone).

- Provide details to the MDL Safety Engineer or MDL Safety Technicians and the cognizant Group Supervisor.

In the absence of personnel, the detection of toxic / corrosive / combustible gases, oxygen deficiency, and increases in gas flows or pressures in gas lines is accomplished through the Building Life Safety System, which will act to shut down the hazardous gases and send an alarm to the JPL Emergency Console. A building evacuation will be automatically initiated through the MDL building fire alarm system if sufficiently high alarm levels are reached. Alternatively, the JPL Emergency Console personnel can manually initiate a fire alarm evacuation or verbally annunciate messages and instructions through the MDL specific or JPL global annunciation system. Evacuation assembly points have been reviewed to be at safe, upwind locations under most conditions.

16.4.2 Chemical Spills (Liquids and Solids)

16.4.2.1 Bodily Contact

General:

- Move as quickly as possible to a safety shower or eyewash station. Flush all affected areas for a minimum of 15 minutes. Reducing the time of chemical contact is critical to minimizing damage to tissue.

- Remove all items of contaminated clothing while flushing affected areas.

- Always have chemical exposures examined by qualified medical personnel.

- Dial 911 (alternate 393-3333 if using a cellular phone) and report chemical exposure.

- It is extremely important that a concise report of the type of chemical(s) and the extent of contact be given to emergency response personnel.

- Report all chemical exposures to JPL Occupational Health Services and your supervisor as soon as possible

- Provide details to the MDL Safety Engineer or the MDL Manager and the cognizant Group Supervisor.

Eyes:

- Request help from a nearby employee to assist you to a wash station.

- Flush eyes for at least 15 minutes while holding eyelids apart to expose as much eye surface as possible.

- Follow General procedures outlined above in this section..

Body:

- Use the emergency shower by pulling the handle.

- Remove clothing from the contaminated area as quickly as you can

- Flush all affected areas for at least 15 minutes.

- Do not put contaminated clothing back on.

- Follow General procedures outlined above in this section.

16.4.2.2 Small Localized Spills:

- Spill containment and control measures can be initiated by building personnel or floor wardens, who have been trained in spill response measures

- The incident must be reported by calling JPL Emergency 911 (alternate 393-3333 if using a cellular phone).

- A copy of the MSDS will be supplied by the MDL Safety Engineer to emergency response personnel.

- Provide details to the MDL Safety Engineer or the MDL Manager and the cognizant Group Supervisor as soon as possible.

16.4.2.3 Major Chemical Spill:

- Report incident to JPL Emergency 911 (alternate 393-3333 if using a cellular phone).

- Evacuate the immediate area.

- If required, administer first aid (qualified personnel only).

- Secure the area in which the spill occurred by erecting barriers and signs.

- If the chemical involved is flammable, attempt to extinguish or eliminate all potential ignition sources.

- If there is no danger, implement measures to confine the spill so that the area requiring cleanup will be minimized. Spill control equipment is available within the MDL and from the JPL Fire Department.

- Provide details to the MDL Safety Engineer or the MDL Manager and the cognizant Group Supervisor as soon as possible.

- Decontamination and waste removal will be handled by the JPL Fire Department, OSO, and EAO

- Any reporting requirements to external agencies will be performed by the JPL Incident Commander and JPL OSO or EAO as appropriate.

- The MDL Safety Engineer, along with the JPL OSO and EAO, will analyze the incident to determine what corrective actions can be implemented to prevent another occurrence or to minimize the impact.

- The MDL Safety Engineer, along with the JPL OSO and EAO, will analyze the overall response to the incident to determine the efficiency and effectiveness of the response and to implement corrective actions as required.

16.4.3 Fires

16.4.3.1 Small and Localized Fires in the H-6 Area

- Alert personnel in the immediate area.

- Dial 911 (alternate 393-3333 if using a cellular phone) and notify the JPL emergency console of the situation.

- Pick up the nearest phone, dial 168 (MDL paging system), and call a floor warden to your location (room address is posted in bold above every phone in the MDL H-6 area). Only floor wardens, who are qualified to use fire extinguishers, should act to suppress the fire.

- If the fire is extinguished, dial 4-3530 (JPL Security Console) or 4-3311 (JPL Fire Department) and describe the situation.
- Provide details to the MDL Safety Engineer or the MDL Manager and the cognizant Group Supervisor as soon as possible.

- Dial 4-4400 (Section Office 384) and describe the situation.

16.4.3.2 Small and Localized Fires in the B-2 Areas

- Alert personnel in the immediate area.

- Dial 911 (alternate 393-3333 if using a cellular phone) and notify the JPL Emergency Console of the situation.

- Go to the nearest secretary office, pick up the phone, dial 168 (MDL paging system), and call a floor warden to your location. Only floor wardens, who are qualified to use fire extinguishers, should act to suppress the fire.

- If the fire is extinguished, dial 4-3530 (JPL Security Console) or 4-3311 (JPL Fire Department) and describe the situation.

- Provide details to the MDL Safety Engineer or the MDL Manager and the cognizant group supervisor as soon as possible.

- Dial 4-4400 (Section Office 384) and describe the situation.

16.4.3.3 Large, Structural, or Fires with a Potential of Explosion

- Evacuate the immediate area.

- Evacuate the building by activating the nearest fire pull station or panic button (red mushroom), and call JPL Emergency 911 (alternate 393-3333 if using a cellular phone).

- General fire notification is automatically sent by activation of the fire alarm. When an evacuation alarm sounds, the building warden or alternate, or in the event of their absence, any available knowledgeable person will call 911 (alternate 393-3333 if using a cellular phone) to confirm the alarm transmission.

- Describe the situation to the first available floor warden.

- Provide details to the MDL Safety Engineer or the MDL Manager and the cognizant Group Supervisor as soon as possible.

16.4.4 Earthquakes

The building seismic event subsystem will shut down all hazardous gases at the source and evacuate the building in the event of an earthquake of sufficient magnitude.

- Get away from hazardous chemicals.

- Take cover (e.g. under a desk, a table, or doorway).

- Listen for evacuation horns or annunciator directives.

- Either evacuate or secure for after shocks, per the assessment of the Incident Commander.

- All chemical storage areas and gas distribution systems should be checked after an earthquake.

- Gas distribution systems should be shutdown manually if the seismic subsystem has not intervened.

- For further emergency information on earthquake safety, consult the JPL Multihazard Emergency Response Plan.

16.4.5 Electrical Emergencies

16.4.5.1 Electrical Shocks/ Electrocutions

- Proceed with extreme caution. If the victim is in contact with an energized circuit, turn off the power. DO NOT ATTEMPT TO PULL OR PRY VICTIM AWAY WITH YOUR HANDS, ARMS, OR CONDUCTIVE IMPLEMENT.

- If the power cannot be turned off, a nonconductive implement may be used to remove the victim from the energized circuit.

- Report the emergency immediately by calling JPL Emergency 911 (alternate 393-3333 if using a cellular phone).

- Move the victim to an area that is safe, if necessary.

- Administer the necessary first aid. If CPR is required, it should be performed only by qualified personnel. Timely response is critical - seconds count!

- Secure the area in which the incident has occurred.

- Help the victim to remain still and calm until medical assistance arrives.

- Provide details to the MDL Safety Engineer or the MDL Manager and the cognizant Group Supervisor as soon as possible.

16.4.5.2 Power Interruptions:

- Get away from hazardous chemicals.

- Assess the situation and listen for evacuation horns or annunciator directives.

- Apprise floor wardens of any dangerous conditions.

- Shut down any equipment that could present a hazard upon uncontrolled restart.

- Await floor warden evacuation orders or other instructions.

Actions initiated automatically:

- Hazardous gases shut down at source.

- Nitrogen purge of continuous hydrogen flow lines is initiated.

- Inorganic, organic, and HVAC exhaust systems switch to emergency power.

- MDL Life Safety System switches to emergency power.

- Specific critical research equipment operations (e.g., DI water, recirculation pumps, specific cryo pumps, etc.) switch to emergency power.

16.4.6 Injuries

- Report the accident immediately by calling JPL Emergency 911 (alternate 393-3333 if using a cellular phone).

- Give an accurate account of the nature of the accident as well as the condition and location of the victim.

- Do not move the victim, unless hazards are immediately present.

- Secure the area in which the accident occurred, including removal of personnel not directly involved in responding to the emergency.

- Administer appropriate first aid (qualified personnel only).

- Provide details to the MDL Safety Engineer or the MDL Manager and the cognizant Group Supervisor as soon as possible.

16.5 ACCIDENT INVESTIGATION

The purpose of an accident investigation is to analyze the incident and determine the appropriate action to be taken to prevent the recurrence of similar accidents. The recognition, collection, and preservation of physical evidence is an important responsibility of First Responders to the scene in an accident investigation. If possible, one should take measures to isolate and disturb the scene as little as possible and provide detailed documentation of all physical evidence.

16.5.1 A thorough investigation shall be conducted and documented for all accidents and near misses.

16.5.2 The responsibility of conducting initial investigations lies with line management and is assigned to the relevant group supervisor, the MDL Safety Engineer, the MDL Manager, and the Section Manager. The JPL Occupational Safety Office is responsible for investigating and analyzing accidents and unusual incidents to determine their causes and / or contributing factors, and initiating appropriate actions to correct hazardous conditions and improve unsafe procedures and practices. (Ref.: "Safety Organization and Responsibilities Safety Manual", DMIE document #1486.) Special Review Boards may be convened if the circumstances warrant it as defined in the DMIE Policy Document # 10391, "Special Review Boards", and the DMIE Procedure Document # 43312, "Special Review Boards".

16.5.3 Pertinent information for the investigation includes:

- What the employee was doing.

- The condition of the general physical surroundings.

- The direct and contributory causes of the accident.

16.5.4 Corrective actions shall be taken to prevent recurrence of the accident.

16.5.5 Accident investigation procedures shall be documented through the use of the JPL Mishap Report (JPL 0554-S). (See Section 4.16.) (Ref.: DMIE Document #1496, "Reporting Mishaps".) This process is administered by the JPL occupational Safety Office and is linked to the NASA Mishap Reporting and Corrective Action System.

16.6 BUILDING SHUTDOWN PROCEDURE

These building shutdown procedures, in the event of a major emergency, document how to bring indicated building systems within the Microdevices Laboratory, building 302, to a safe powered-down status. Descriptions previously given in Sec. 16.4 describe how the facility automatically responds to various incidents and typically result in a safe operating state.

Initiation of manual shutdown procedures must be coordinated with the JPL Fire Department.

16.6.1 Critical Building Functions Overview

16.6.1.1 Fire Systems:
- Fire sprinkler heads
- Hose cabinets
- Post indicator valve
- Standpipe outlets
- Fire sprinkler riser
- Sprinkler connection
- Fire alarm / Building Evacuation System
- Fire doors / magnetic door closures
- Incipient Fire Detection system
- Smoke dampers
- Fire Department key lock box

16.6.1.2 Air Handling Systems:
- HVAC Air Handlers
- Oil mist exhaust
- Organic exhaust

- Inorganic scrubbed exhaust
- Controls (Staeffa systems monitored by EMS)

16.6.1.3 Electrical:
- Main electrical disconnect
- Emergency generator
- Motor control center
- Uninterruptible power supply

16.6.1.4 Utilities:
- City water
- Sanitary sewer system
- Electrical power
- ~~City natural gas~~ (There is NO hook-up to MDL, bldg. 302)

16.6.1.5 Chemical Processes:
- Process gases
- Chemical storage
- Exhaust scrubbers
- Reverse osmosis deionized water system
- Liquid nitrogen system

16.6.1.6 MDL Life Safety System:
- Toxic / corrosive / pyrophoric gas monitoring system
- Combustible gas monitoring system
- Oxygen monitoring system
- Smoke / heat detection system
- Incipient Fire Detection system
- Pendant alarm system (electronic buddy)
- Seismic shutdown system
- Liquid leak sensing and locating system
- Chemical spill monitoring system
- Uninterruptible power supply

16.6.1.7 Miscellaneous:
- Elevator bleed-off valve

16.6.2 Fire Systems

16.6.2.1 Fire Sprinkler Heads:

- Each fire sprinkler head will release water only when heated to the temperature that melts the center fusible link.

- Once water begins to flow, a fire alarm will automatically sound throughout MDL and be sent to the JPL Emergency Console. If an evacuation alarm sounds, the

building warden or alternate will contact the JPL Emergency Console (Zebra Control) at 4-3530, or, in their absence, any available person will dial 911 (alternate 393-3333 if using a cellular phone) to confirm the alarm transmission once the building evacuation is complete.

- Fire sprinklers are located in the ceiling, above the ceiling in the interstitial areas, and inside critical pieces of equipment such as gas cabinets and exhaust duct systems with an internal diameter of 10 inches or greater.

- To stop water flow from fire sprinkler heads, three situations exist:

  • For one to four fire sprinkler heads, fire sprinkler stops, wedges of wood, or fire sprinkler shutoff tools should be used. This may be performed only in coordination with the JPL Fire Department.

  • For multiple heads, the system will have to be shut down. Remember, the JPL Fire Department must give permission before the fire system can be shut down. (See Post Indicator Valve below.)

  • For a single floor shut down, the control valve for the specific floor will be shut down, including separate control valves for exhaust system sprinklers. This is a fire department operation only.

16.6.2.2 Post Indicator Valve:

- The post indicator valve (PIV) is located outside the second floor lobby at the northeast corner of MDL.

- The valve is equipped with a tamper switch that will sound an alarm if turned off to the "CLOSE" position.

- The fire system must never be shut down without JPL Fire Department approval.

- To turn the system off (or on), remove the padlock, remove and invert the handle, and turn counterclockwise to shut off or clockwise to open. Keep turning the valve until it is fully open or closed.

16.6.2.3 Fire Riser:

- The fire riser is the valve system controlling fire sprinkler water from the PIV to the fire branch lines on each floor.

- Additional fire sprinkler heads and a wrench are located with the riser on the first floor, room 302-115 at the east end of the MDL building.

16.6.2.4 Fire Alarm/Building Evacuation System

- The fire alarm building evacuation system is an alarm system that will sound when a fire sprinkler flow alarm, smoke alarm, pull station, heat detector, red mushroom button, or the incipient fire detection system is activated.

- Only through coordinating with the JPL Fire Department can this system be powered down.

- This system is automatically activated once a pull station, smoke, heat or incipient fire detector, fire sprinkler flow switch, red mushroom button, or building life safety system alarm occurs. If an *evacuation alarm* sounds, the building warden or alternate will contact the JPL Emergency Console (Zebra Control) at 4-3530, or, in their absence, any available person will dial 911 (alternate 393-3333 if using a cellular phone) to confirm the alarm transmission once the building evacuation is complete.

16.6.2.5 Fire Doors:

- In a fire, once all employees have been evacuated, all doors in the facility should be shut by the building or floor wardens to slow the progress of the fire.

- Fire doors should also be shut in hazardous gas leaks, hazardous chemical spills, and any time the facility is shut down or unoccupied.

16.6.2.6 Fire Department Key Lock Box:

- The Fire Department key or lock box is located on the second floor by the northeast lobby next to the elevator controls.

- Emergency keys for MDL are secured in this locked box.

- The JPL Fire Department has a key to this box.

- Additional building specific emergency keys are kept in the Key Lock Box in the first floor MDL Control Room (302-139). The MDL Safety Engineer has a key to this box.

16.6.2.7 Fire hose cabinets at the east end entrances to stairwells and west end stairwells may be accessed and utilized by Fire Dept. (trained) personnel only as per NASA directive in "NASA Safety Standard (NSS) 8719.11 for fire protection".

16.6.2.8 Standpipe outlets in the west end hose cabinets and east end stairwells are for fire department use only.

16.6.2.9 The sprinkler connection at the north-east exterior corner of the building can be used by the JPLFD in the event of domestic water interruption.

16.6.2.10 Fire dampers are automatically activated and change state in the event of fire detection

16.6.3 Exhaust/Air-Handling Systems

16.6.3.1 The three separate exhaust systems used at the MDL are:

- Oil mist - Used for oil pump systems involved in nonhazardous operations.

- Organic - This galvanized steel duct system is used for solvent exhaust.

- Inorganic scrubbed - This fire-resistant fiberglass reinforced polyester (plastic) duct is for acid / alkali and fabrication process tool exhaust.

16.6.3.2 Exhaust systems may be shut down at three locations:

- The motor disconnect (by each exhaust fan motor).

- The motor control center located at the north side of room 302-236, between air handlers AH3 and AH4.

- JPL EMS through the Staeffa controls

16.6.3.3 Exhaust systems are backed by the MDL emergency generator

16.6.3.4 All air handlers may be controlled from the motor control center (see 16.6.3.5) or JPL EMS. There are six main air handlers for MDL (see Section 8.3).

16.6.3.5 Motor Control Center

- The motor control center is located at the north side of room 302-236, between air handlers AH3 and AH4.

- This electrical panel will shut down all air intakes and exhaust systems.

- The *motor disconnects* are located by each exhaust fan motor.

16.6.4 Electrical

16.6.4.1 Main Electrical Disconnect

- The main electrical disconnect for the MDL facility is located on the second floor at the east entrance and outside the building on the first floor next to the emergency generator.

- To operate the second floor control, simply operate the key switch.

- To operate the first floor control, open the outer panel door and turn the large black handle 90 degrees counterclockwise.

- The emergency generator will start automatically if the primary power to MDL is shut off.

- To effect a complete electrical shutdown of the facility, the emergency generator will need to be shut down.

16.6.4.2 Emergency Generator

- The MDL emergency generator is located on the first floor outside next to the utility pad (southeast corner).

- The generator supplies power to the alarm and monitoring systems, paging and evacuation systems, and other life safety functions, such as ventilation and exhaust to the H-6 areas.

- The emergency generator system will start itself in the event of a power failure.

- The system can be manually started or shut down at its control panel.

16.6.4.3 Uninterruptible Power Supply

- One uninterruptible power supply (UPS) is located on the first floor of the MDL building in Control Room (Monitoring and Control Center), 302-139.

- A second UPS is located on the third floor in room 326A.

- These two UPS systems serve as the battery backup for the safety systems and the HVAC control system.

- A third UPS system is located on the second floor in 302-236 and supports the e-beam lithography system in 302-101B.

16.6.5 Utilities

16.6.5.1 City Water

- City water can be shut down at two locations:

  • On the first floor in room 302-115.

  • By the underground valves located outside the utility pad on the southeast corner.

16.6.5.2 City Gas
- MDL does not use city gas.

16.6.6 Chemical Processes

16.6.6.1 Process Gases

- Process gases are located in the Hazardous Gas Bunker, the Hydrogen gas bunker, and in the chase areas of the H-6 area.

- Process gases are turned off by:

  • Activation of the toxic or flammable gas monitor alarm

  • Activation of the seismic, exhaust, or ventilation alarm

  • Activation of the emergency shutoff (panic) buttons.

  • Manually shutting off the automated gas control boxes or turning the cylinder valves (the latter requires the buddy system).
  Note that the gas cabinets also have self-monitoring functions which can initiate an automatic shutdown. (See Sections 8.4.2.2 and 11.2.5.)

  • Interior gas cabinets and the Hydrogen bunker six packs may be shut down by opening the Emergency Nitrogen Static Pressurized Gas System which holds open interior gas source valves. One manual valve is located in the entry aisle 302-144, outside of the MDL Control Room 302-139. The other valve is located at the southeast corner of the building exterior and is activated by automatic control.

16.6.6.2 Chemical Storage Areas
- All chemical storage areas must be checked after an earthquake or other major emergency.

16.6.6.3 Exhaust Scrubbers (See Sections 8.2.1 and 8.2.4)

16.6.6.4 Acid Neutralization System

- The acid neutralization system is located on the utility pad, but is not operational (since all liquid chemical waste except water is collected in MDL).

- If needed, the building effluent stream (mostly water) may be shut down by closing the outflow valve of this system.

16.6.6.5 Reverse Osmosis Deionized Water System

- The RODI water system is located on the utility pad by the acid neutralization system.

- The system can be shut down by turning off the power at switch No. 1 located on the control panel.

16.6.6.6 Liquid Nitrogen Tank

- Three LN2 tanks are located on the southeast corner of building 302. (See Section 8.1.)

- The tanks can be shut down by closing both the cryogenic valves located at the bottom of the tanks or, in the case of the large tank supplying the building nitrogen gas needs, by closing the valves on the two feeder manifolds located directly behind the tanks.

16.6.7 MDL Life Safety System

16.6.7.1 Toxic Gas Monitor

- MDL uses three MDA 16-point monitoring systems to monitor the following hydrides and mineral acids:

AsH_3	NH_3	H_2Se
PH_3	HF	Cl_2
SiH_4	HCl	SiH_2Cl_2
B_2H_6	BCl_3	H_2S

- These systems may be shut down by the key switch located at the bottom of the units or by the breaker panels to which they are hard wired.

- Refer to Appendix 14 for alarm point locations.

- Certain toxic operations have also been provided with dedicated MDA CM4 units to allow a faster response, greater protection, and immediate local shut-

down of equipment. Portable monitors are also available for maintenance and response operations.

- MDL Toxic gas alarm response levels (Room):

Low Alarm	0.5 TLV	"Alert / Shut-down"
High Alarm	1 TLV	"Evacuate"

- MDL Toxic gas alarm response levels (Enclosures-- Set at a higher level to increase response times):

Low Alarm	1 TLV	"Alert"
High Alarm	10 TLV	"Evacuate"

16.6.7.2 Combustible Gas / Oxygen Monitor

- The combustible gas / oxygen detection system (Sierra Monitoring Control system) is located in Control Room (Monitoring and Control room) 302-139 on the first floor, next to the MDA toxic gas systems.

- The combustible gas / oxygen detector monitors 35 points within the process tool and cleanroom areas for H_2 and CH_4 and 7 points for oxygen deficiency.

- This system may be shut down by the breaker panel UPS-1 in room 302-139.

- Refer to Appendix 14 for alarm point locations.

- MDL Combustible gas alarm response levels:

Low Alarm	0.2 LEL	"Alert / Shut-down"
High Alarm	0.5 LEL	"Evacuate"

Since the Combustible sensors are calibrated for hydrogen which has an LEL of 4.1%, a low level alarm will be activated if 0.8% of hydrogen is detected, and a high level alarm is initiated if 2% or more of hydrogen is detected.

- MDL Oxygen Deficiency alarm response levels:

Low Alarm	19.5% O2	"Alert"
High Alarm	16.5% O2	"Evacuate"

Room air typically has 20.95% by volume of oxygen. Refer to Section 10.21 for further information on the effects of oxygen deficiency.

16.6.7.3 Seismic Detection Systems

- Two seismic detection systems are located in the MDL Control Room (Monitoring and Control Center) 302-139.

- These systems will automatically shut down process gases and other critical functions in the event of an earthquake of sufficient magnitude.

- These systems may be shut down at the units by their power switches.

- In addition, a third centralized JPL seismic monitoring system which reports to JPL's EMS has been installed in MDL. It provides monitoring data, but no direct control functions.

16.6.7.4 Liquid Leak Sensing and Locating System

- The TraceTek liquid leak sensing and locating system will detect liquid leaks in the cleanroom chemical trenches, sound an alarm, and display the leak location.

- The unit is located in the MDL Control Room 302-139 on the first floor.

- This system may be shut down at the unit by its power switch.

16.6.7.5 Uninterruptible Power Supply (See subsection 16.6.4.3)

16.6.7.6 Incipient Fire Detection (IFD) System

- Graphic annunciator panel is located in Control Room 302-139 with actual system control panels and cloud chambers located in the center aisle of the cleanroom plenum, Room 302-237.

- Detects precursor emissions to a fire.

- This system may be shut down at the breaker panel UPS-1 in room 302-139.

16.6.7.7 Pendant Alarm System (i.e. Electronic Buddy System)

- Pendants worn around users neck sends room specific distress signal to JPL Emergency / Security Console (Zebra Control) when activated.

- Displays location and phone number programmed into pendant.

16.6.8 Miscellaneous

16.6.8.1 Elevator Bleed-Off Valve

- The elevator bleed-off valve is located on the first floor in room 302-114. Only the JPL Fire Department and JPL Security have keys to this area.

- By bleeding off the hydraulic fluid, the elevator can be lowered to remove possibly trapped employees.

- The elevator recall location is on the second floor.

16.7 EMERGENCY PREPAREDNESS

The use of extremely and acutely hazardous gases in MDL poses a potential hazard and therefore a possible target for tampering during rioting, civil unrest, or terrorist acts. However, based on multiple fail-safe redundancies built into the gas distribution system described below, MDL is considered to be prepared for potential civil disturbance or tampering.

16.7.1 MDL Life Safety System

The MDL Building Life Safety System is a three-tiered system with the primary tier being the JPL Emergency Control Console located at JPL Security (Zebra Control). This station is staffed 24 hours a day by JPL Plant Protection personnel.

The second tier of the MDL Safety System is represented by the Local Emergency Control Station functions located in the MDL Control Room (MDL Monitoring and Control Center) 302-139, adjacent to the entry to the main cleanroom area. All of the equipment items located in room 302-139 are connected to an emergency generator through an uninterruptible power supply system.

The third tier of the MDL Safety System consists of the following subsystems that are interfaced to a supervisory computer system:

- MDA toxic / corrosive / pyrophoric gas detection system
- SMC combustible gas / oxygen detection system
- PCSI seismic detection system
- PCSI manual emergency shut-off subsystem (red mushroom panic buttons) for hazardous gases
- Tracetek fluid-leak detection and location system
- ADT / Notifier Fire / smoke / heat detection system
- Environment One Incipient Fire Detection system
- Inovonics pendant alarm system
- Exhaust failure detection system
- Emergency power generator system
- Mark Systems wet bench station fire detection / suppression system
- Gas cabinet status for hazardous gases system

16.7.2 Applicable documents

- Uniform Building Code
- Uniform Fire Code
- 29CFR1910.1000 and sub-part Z
- Toxic Gas Ordinance AB-1021

16.7.3 System Provisions

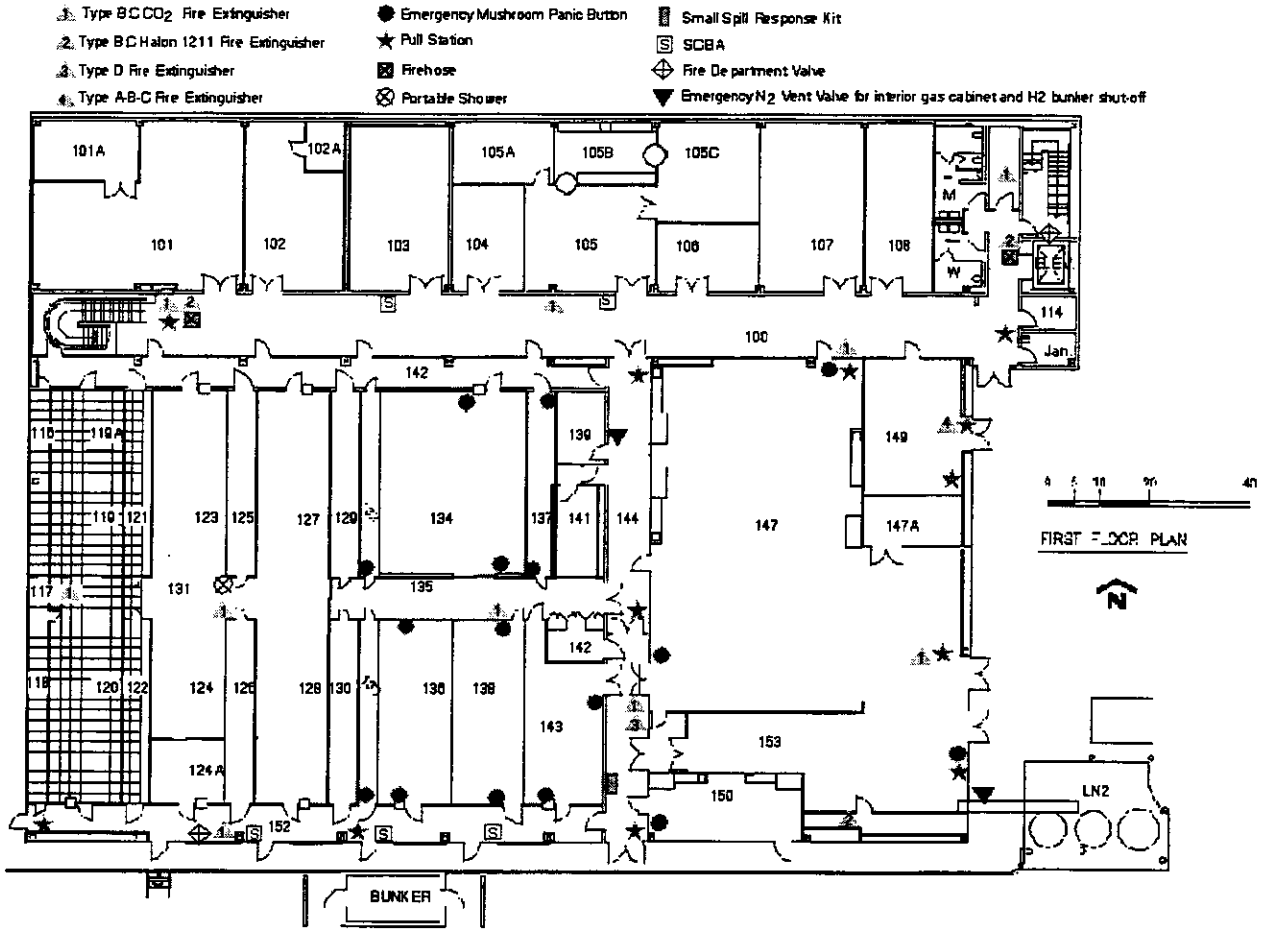
To provide emergency shut-down of hazardous gases, the gas cabinet control assemblies are interfaced with the supervisory computer control system, which may

initiate an emergency shut-down signal. Isolation of hazardous gases at the source will be effected under any of the following conditions:

- Toxic / corrosive / pyrophoric gas detection by the MDA systems
- Combustible gas detection by the SMC system
- Seismic disturbance detection by the PCSI system
- Activation of the MDL fire alarm system
- Remote intervention by JPL security or fire officials
- MDL exhaust system failure
- Building power failure
- Activation of any manual PCSI system Emergency Shutoff (ESO) button
- Excess flow condition on any of the hazardous gas plumbing lines
- Excess pressure condition on any of the hazardous gas plumbing lines

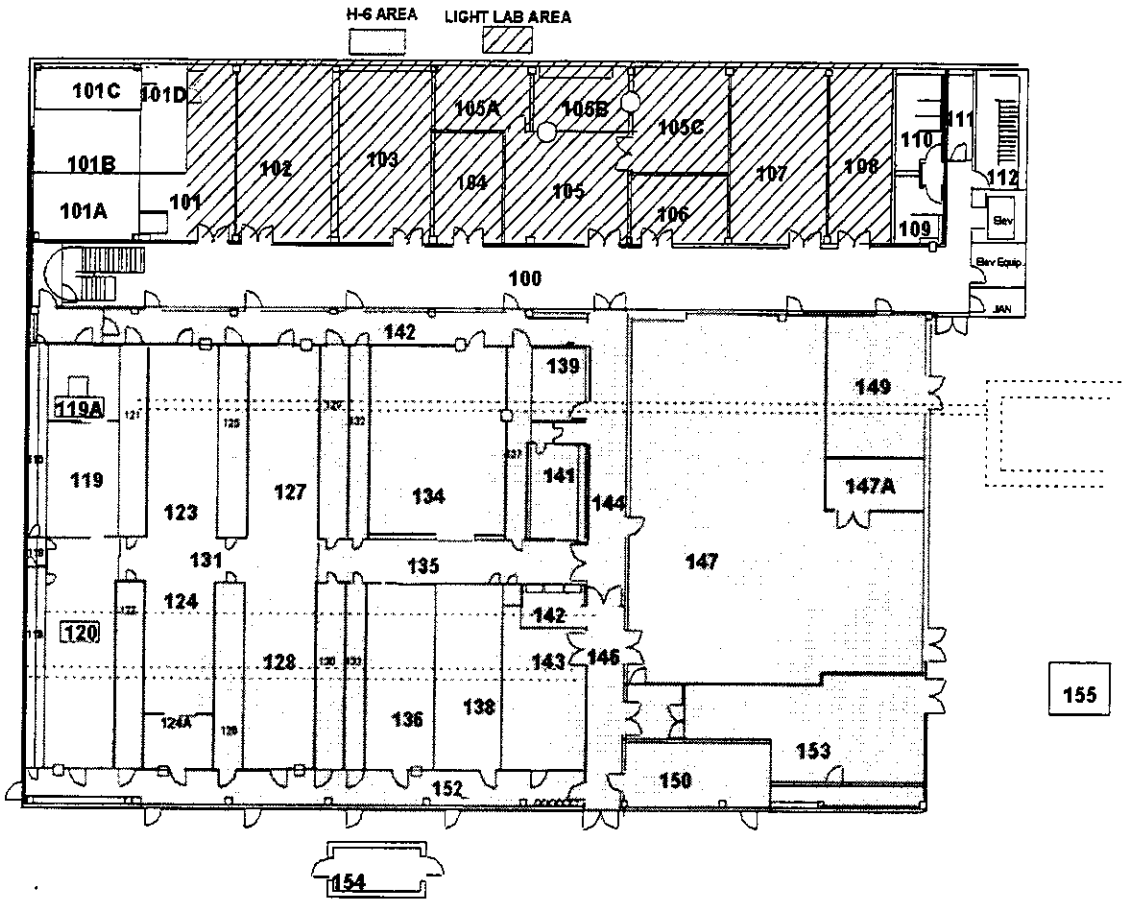
Emergency shutdown of process gases can be accomplished automatically by signals originating from the gas detection systems, from the manual emergency shutdown system, from the remote JPL Emergency Console or by any of the other systems indicated above.

Appendix 1



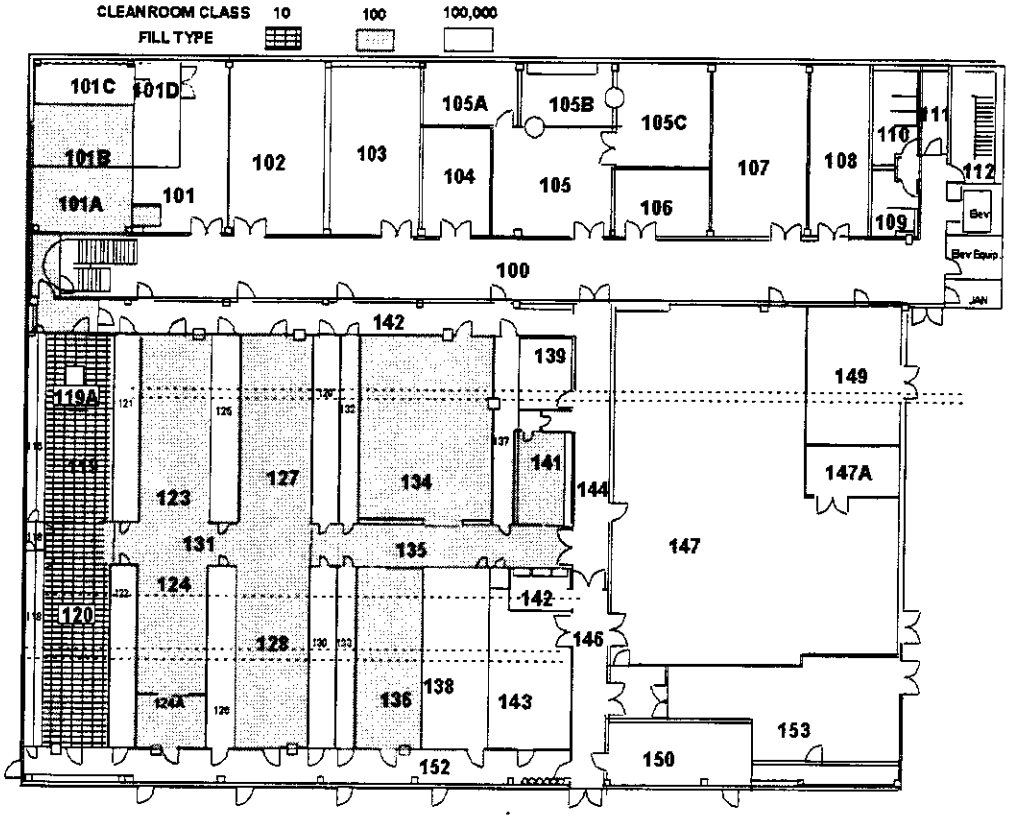
MDL First Floor Layout with Emergency Equipment

Appendix 2



H-6 and Light Lab Areas (first floor)

Appendix 3



Cleanroom Areas (first floor)

Appendix 4

JET PROPULSION LABORATORY INTEROFFICE MEMORANDUM

TO: James L. Lamb
Manager, Microdevices Laboratory

DATE:

FROM:

SUBJECT: Temporary H-6 access

This memo is to request temporary cleanroom access for:

Date and duration of requested access:

Purpose of visit - Include specific H-6 area and work to be performed:

MDL Escort / Contact:

Approved: _____ _____
MDL Group Supervisor, Date

Approved: _____ _____
James L. Lamb
Manager, Microdevices Laboratory (MDL) Date

Cleanroom Protocol and Safety Guidelines

Completed: _____ _____
Amy Posner, Safety Engineer,
Microdevices Laboratory Date
Sec. 384

YEAR: _____

MDL AUTHORIZATION FORM

Name: _____ Employee Number: _____ Phone: _____

Address: _____ E-mail: _____

Category (Check one)

- ☐ JPL, Section: _____
- ☐ DVS /DIF (Distinguished Visiting Scientist / Distinguished Industrial Fellow)
- ☐ Industry: _____
- ☐ Academic Part Time
- ☐ Other. Explain: _____
- ☐ University: _____
- ☐ Student, Undergraduate
- ☐ Student, Graduate
- ☐ Advisor name: _____
- ☐ Faculty, Title: _____

Project Description: _____

_____ Anticipated End Date: _____

U.S. Citizen: ☐ Yes ☐ No If No, Country: _____ Green Card: ☐ Yes ☐ No (VISA#: _____)

To the proposed user - please read the following carefully:
We expect all users of the JPL Microdevices Laboratory (MDL) to follow the policies, rules, guidelines, and protocols as set down in the Microdevices Laboratory Safety Manual at <http://mdlwww>. This means that all MDL users must receive and understand the safety training and cleanroom practices prior to using (or even entering) the cleanroom. Your laboratory access privileges are contingent upon your strict adherence to safety regulations and on your following MDL practices for maintaining our cleanroom environment.

User _____ Date _____

APPROVAL SIGNATURES
All projects involving outside users and university supported students in particular, require a JPL/MDL Group Supervisor's approval. By signing on to a project, the Group Supervisor acknowledges that he/she has spoken with the user (and in the case of students, with the student's university research advisor) and explained the MDL charges which will be incurred by their contract(s). The MDL Group Supervisor is responsible for having the required paperwork implemented for establishing a charge number. This supervisor's tasks will be liable for the charges if the funds are not put in place.

	NAME	SIGNATURE	DATE
University Advisor/Sponsor/ Immediate Supervisor			
MDL Group Supervisor			
Cleanroom Contact/Mentor			
Section 384 MDL Manager			

FUNDING BASE (for MDL charges incurred) -- Associated tasks and charge numbers: _____

Anticipated Category: ☐ General ☐ Light C/R User ☐ Heavy C/R User (>50 hrs/6 mos)

Access Requested: ☐ Non H-6: ☐ 6 a.m. to 8 p.m. ☐ 24-hour access ☐ H-6: ☐ 6 a.m. to 8 p.m. ☐ 24-hour access ☐ Cleanroom: ☐ 6 a.m. to 8 p.m. ☐ 24-hour access

Distribution:
MDL Safety Engineer (original); MDL Manager; Supervisor of Central Processing & MDL Support Group; Authorizing Group Supervisor(s); University Sponsor, where applicable; MDL Cleanroom User Contact / Mentor; and User.

CERTIFICATION RECORD

Name:_____ Employee Number: _____

Safety Training Completed:

MDL Safety Engineer: _____ Date: _____

Cleanroom Practices Training Completed (required for cleanroom envelope access only):

MDL Process Leader: _____ Date: _____

Cleanroom Practicals Training Completed (required for Fully Qualified status):

Designated Mentor:_____ Date: _____

MDL Process Leader: _____ Date: _____

Cleanroom User Senior Status Achieved (required to act as a Mentor):

MDL Process Leader: _____ Date: _____

Cleanroom User Experience Level:

☐ **Trainee/New Hire** ☐ **Fully Qualified** ☐ **Senior**

Mentor for: _____

Trainer for: _____

Cognizant Engineer of: _____

COMMENTS OR SPECIAL RESTRICTIONS?_____ (____ PAGES ATTACHED)

Distribution:
MDL Safety Engineer (original); MDL Manager; Supervisor of Central Processing & MDL Support Group; Authorizing Group Supervisor(s); University Sponsor, where applicable; MDL Cleanroom User Contact / Mentor; and User.

Appendix 6

JPL
4800 Oak Grove Drive
Pasadena, CA 91109 - 8099

HAZARDOUS WASTE

20888

1. ACCUMULATION START DATE _____

2. NAME _____
   PHONE _____

3. SECTION _____ BUILDING _____ ROOM _____
4. PROCESS GENERATING WASTE/SOURCE CODE _____
5. PHYSICAL STATE
   - ☐ SOLID
   - ☐ LIQUID
   - ☐ GAS

6. QUANTITY
   - _____ POUNDS
   - _____ GALLONS
   - _____ CUBIC FEET

7. HAZARDOUS PROPERTY (I - IGNITIBLE, C - CORROSIVE, R - REACTIVE, T - TOXIC) _____

8. CHEMICAL NAME(S) (IF MIXTURE, INCLUDE % OR CONCENTRATION OF EACH COMPONENT):	9. % OR CONCEN-TRATION

JPL 2799-S R 10/85

10. WASTE DISPOSAL FORM COPIES: SEND WHITE COPY TO EAO 171-225. ATTACH REMAINING COPIES TO WASTE CONTAINER.
11. DATE QUANTITY LIMITATION IS REACHED _____

* This is an example only. These forms are available through JPL EAO or from JPL electronic forms. A unique number and bar coding must be assigned to each. Some blanks are maintained at MDL. Contact the MDL Safety Engineer or MDL Safety Technician for further assistance.

Appendix 7

Explosive-Forming Organic Peroxides

A. 3-Month Storage Limit. The following materials must be disposed of after 3 months.

Absolute ethers (ethyl ether anhydrous)

bis(2-methoxyethyl)ether (diethylene glycol; dimethyl ether; diglyme)

Diethyl ether (ethyl ether; ethyl oxide; ethylic ether)

Dioxane (diethylene oxide)

Divinyl acetylene

Glyme (1,2-dimethoxyethane)

Isopropyl ethers

Potassium metal

Sodium amide (sodamide)

Tetrahydrofuran (cyclotetramethylene oxide)

Vinylidene chloride (1,1-dichloroethylene)

B. 6-Month Storage Limit. The following materials must be disposed of after 6 months.

Acetal

Acrolein (propenal; acrylic aldehyde; allyl aldehyde)

Acrylonitrile (propene nitride; vinyl cyanide)

Alkyl-substitute cycloaliphatics (methyl, ethyl cyclo ___ ane)

All other ethers

Butadiene (erythrene)

Chloroprene (2-chloro-1,3-butadiene; chlorobutadiene)

Chlorotrifluoroethylene

Cumene (isopropyl benzene; 2-phenylpropane; cumol)

Cyclohexane (hexahydrobenzene; hexamethylene)

Dealin

Dicyclopentadiene

Liquid paraffins with branched chains

Methyl Acetylene (allylene; propyne)

Methycyclopentane

Methyl 1-butylketone (2-hexanone; n-butyl methylketone)

Methyl methacrylate

Olefins (unsaturated hydrocarbons; propene, hexene, ___ ene)

Styrene (phenylethylene; styrene monomer; vinylbenzene)

Tetrahydronaphthalene

Tetrafluoroethylene (perfluoroethylene; TFE)

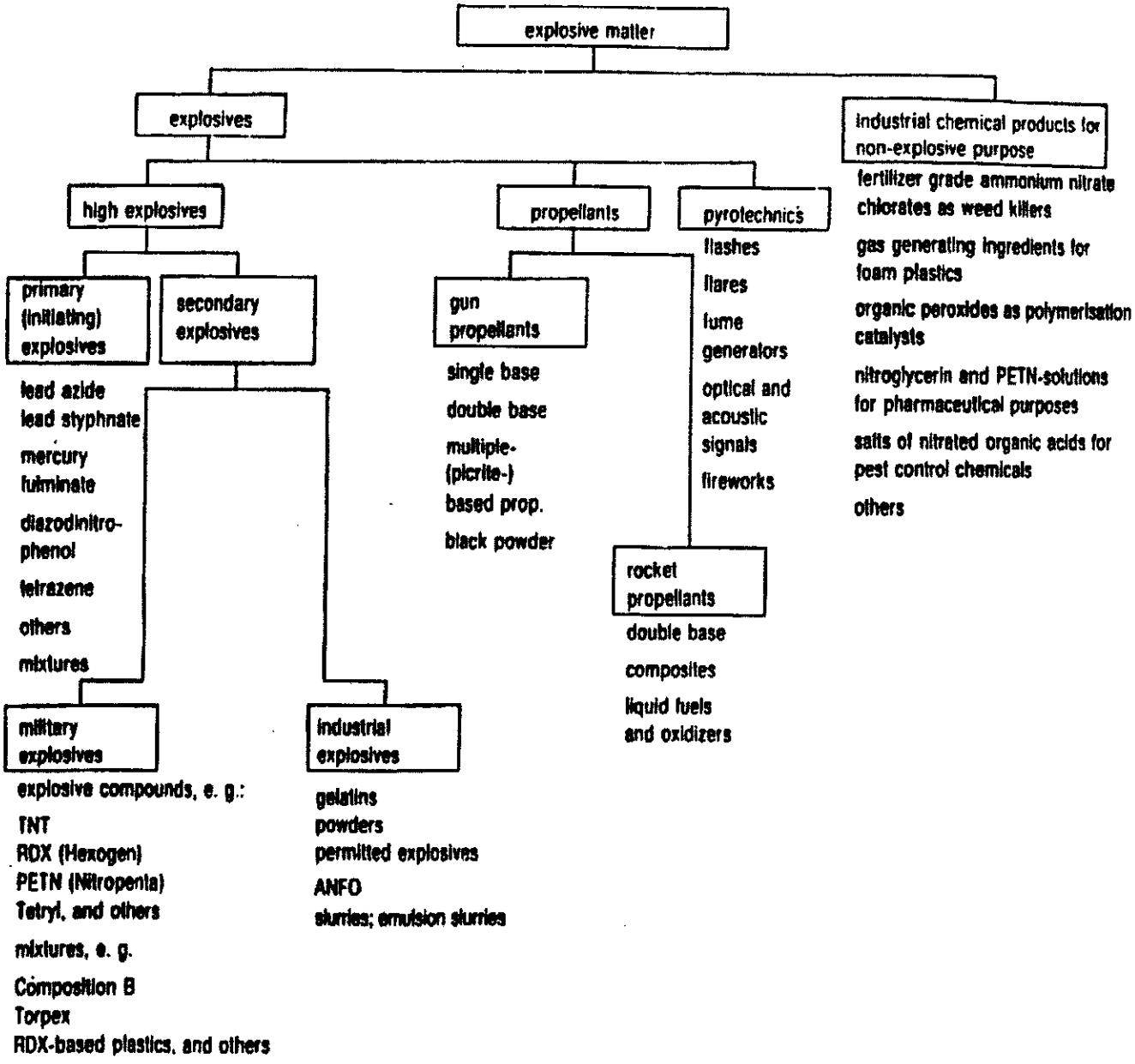
Vinyl acetate

Vinyl acetylene

Vinyl chloride (chloroethylene; chloroethene)

Vinylpyridine

Appendix 8



Explosive Materials and their Applications

Appendix 9

Uniform Fire Code Permitted Quantities of HPM in a Single Fabrication Area
(Table No. 51.105-A)

MATERIAL	MAXIMUM QUANTITY
Flammable liquids	
Class I-A	90 gal.
Class I-B	180 gal.
Class I-C	270 gal.
Combination flammable liquids	360 gal.
Combustible liquids	
Class II	360 gal.
Class III-A	750 gal.
Flammable gases	9,000 cu. ft. at one atmosphere of pressure at 70?F
Liquefied flammable gases	180 gal.
Flammable solids	1,500 lbs.
Corrosive liquids	165 gal.
Oxidizing material – gases	18,000 cu. ft.
Oxidizing material – liquids	150 gal.
Oxidizing material – solids	1,500 lbs.
Organic peroxides	30 lbs.
Highly toxic material and poisonous gas	Included in the aggregate for flammables as noted above

Appendix 10

Uniform Fire Code Maximum Quantities of HPM (Table No. 51.106-B)

HPM materials in use in a work station shall not exceed:

Flammables and gases	3 cylinders
Toxics Combined	liquids 15 gallons
	solids 5 pounds
Corrosives	gases 3 cylinders
	liquids 25 gallons[1]
	solids 20 pounds
Oxidizers	gases 3 cyliners
	liquids 12 gallons[1]
	solids 20 pounds

[1] An equal amount of nonflammable HPM liquid in reservoirs of filtering systems of connected materials in use shall be permitted.

Appendix 11

MDL Management, Warden and Gas Handler Roster

MDL MANAGEMENT

TITLE	NAME	PHONE	ADDRESS	MAIL STOP
Manager, Section 384	Carl Ruoff	4-3599	302-212	302-205
Deputy Manager, Section 384	TBD			302-205
MDL Manager	James Lamb	4-5019	302-219	302-205
Safety Engineer, Microdevices Laboratory	Amy Posner	4-9635	302-222	302-231
Facilities Engineer, Microdevices Laboratory	Hugo Velasquez	4-0079	302-103	302-231

MDL Warden Roster

MDL WARDEN NAME	LOCATION	PHONE	ADDRESS	MAILSTOP
James Lamb+	302- 2nd floor	4-5019	302-219	302-205
Hugo Velasquez	302-1st floor	4-0079	302-103	302-231
Suzi Martin	302-1st floor	4-7076	302-306N	302-306
Pat Patterson	302-1st floor	3-2529	302-205D	302-231
Keith Fields	302-1st floor	4-1331	302-103	302-231
Steven Jurewicz	Bldg. 297	3-0420	297-101C	302-231
Rich Muller	302-1st floor (Alternate)	4-7470	302-105	302-306
Jeff Stern	Bldg. 129 (Alternate)	4-0029	302-306P	302-306
Amy Posner	302-3rd floor	4-9635	302-222	302-231
Marc Foote+	Bldg. 129	4-9009	302-218	302-231

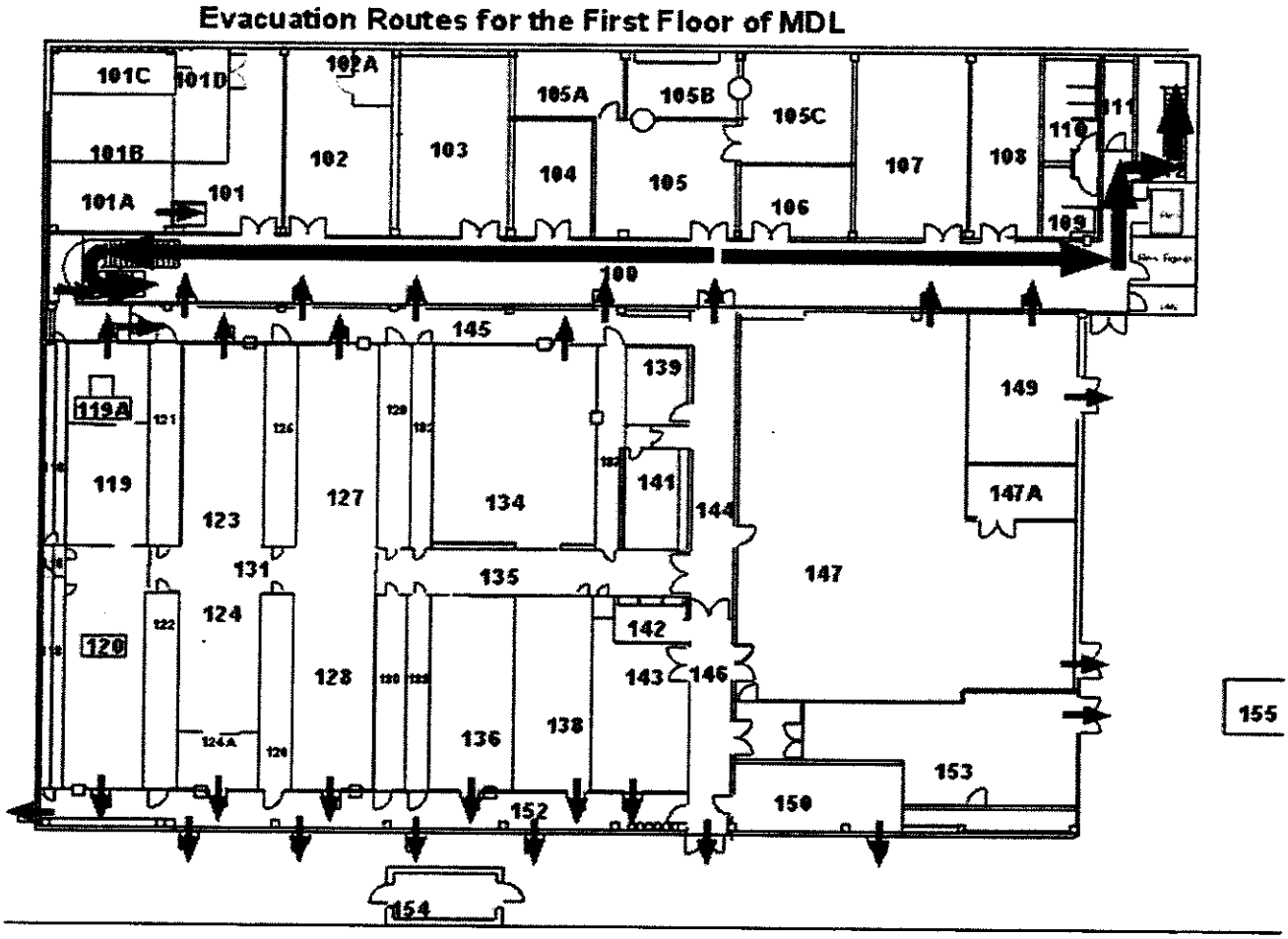
+Building Warden

MDL Gas Handler Roster

MDL GAS HANDLER NAME	GASES	PHONE	ADDRESS	MAILSTOP
James Lamb	All	4-5019	302-219	302-205
Hugo Velasquez	All	4-0079	302-103	302-231
Keith Fields	Hydrogen Only	4-1331	302-103	302-231

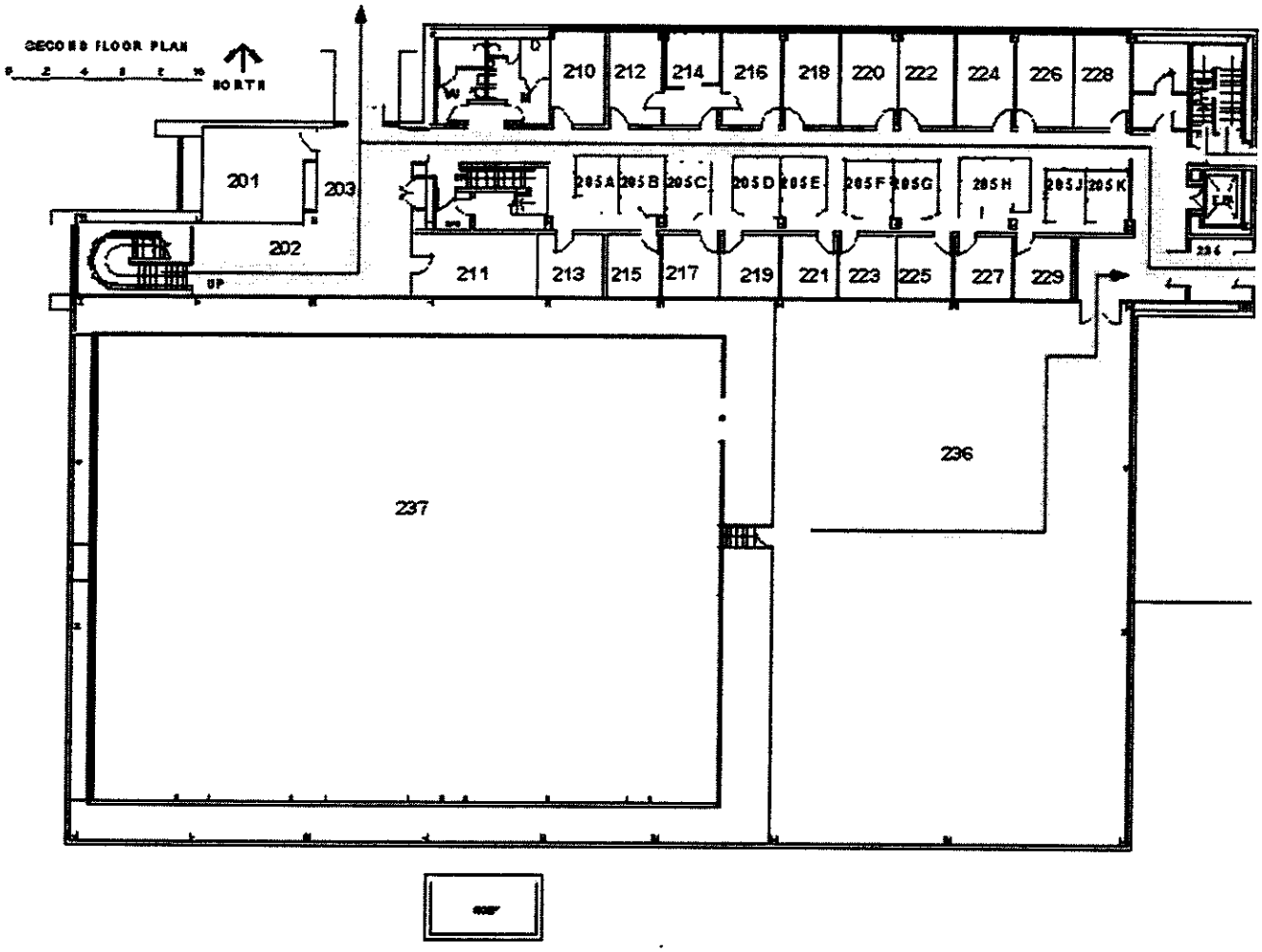
Appendix 12

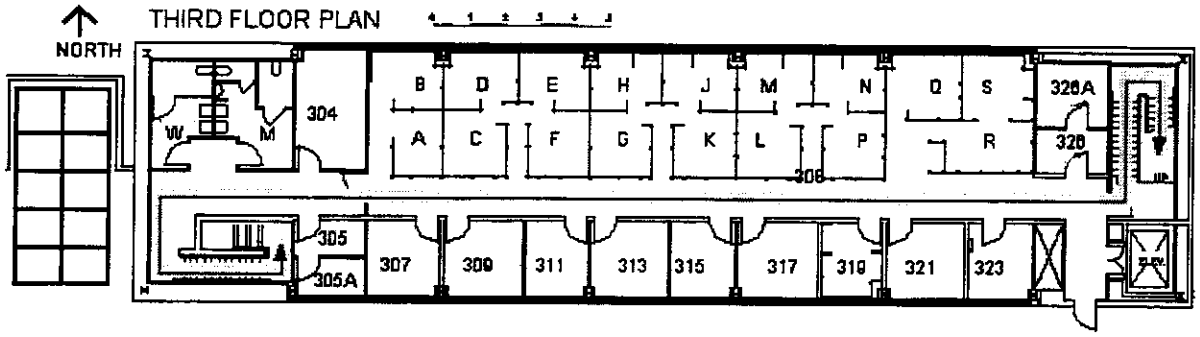
EVACUATION ROUTES AND ASSEMBLY AREAS

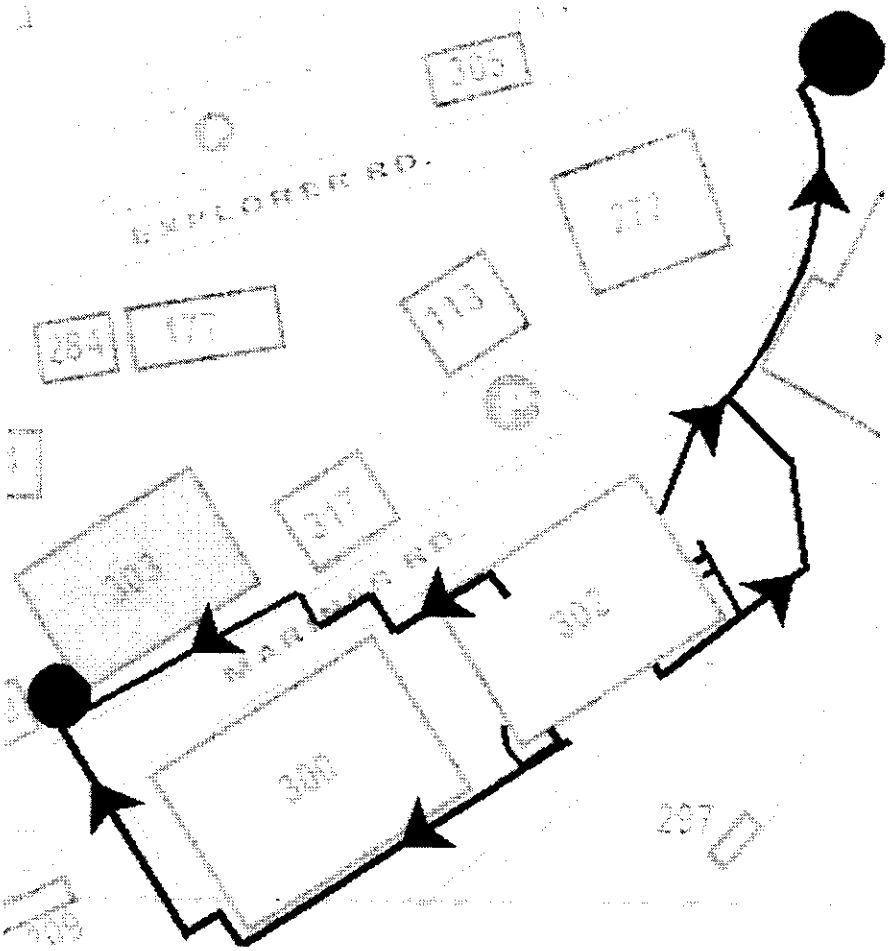


Evacuation Routes for the First Floor of MDL

EVACUATION ROUTE







Evacuation Assembly Areas for MDL

BUILDING EVACUATION DRILL PROCEDURES

1. As a minimum, each building shall participate once a year in an evacuation drill. The Office of the Emergency Preparedness Administrator shall develop and publish, in concert with the JPL Fire Department, a quarterly schedule of buildings that shall participate. (Ref: NASA Procedures and Guidelines 8715.2 / NFPA 101 31-1.5.1,.3)

2. The Fire Department Officer-In-Charge, who will be the Drill Coordinator (CD), will contact the Building Warden not more than 1 week prior to the scheduled date, and not less than 2 hours prior to the actual evacuation drill, to determine if any "Mission Critical" operations in progress or scheduled to be in progress, must not be disrupted. All other activities within the building shall be subject to the evacuation drill exercise. Ref: OSHA 29 CFR Appendix to Subpart E 1910.38 (a).

3. Prior to initiation of a drill in a given structure, all support personnel shall be briefed on the drill at hand, and given their assignments by the Drill Coordinator (CD). The person(s) assigned to monitor the area excused from drill participation shall be notified by the DC at this point.

4. As a minimum, the following support personnel shall be assigned to observe:

a. (1) person per floor, or 2 floors, depending on building size, plus exit

stairwells serving the monitored area.
b. (1) person to monitor performance of Building Warden and document floor and building evacuation times for post-drill critique- If possible, the DC will perform this function.
c. (1) person to evaluate movement of occupants along evacuation routes to designated emergency assembly area(s).

5. Upon notification from the DC that the simulated fire has started, the Building Warden shall activate an alarm pull station, exit the building, proceed to the designated emergency assembly area via the designated evacuation route.

6. Floor Wardens or their alternates shall conduct a sweep of their respective floors insuring:
a. All occupants have exited, and handicapped have been assisted as required.
b. Self closing doors on evacuation routes are held open till all evacuees have passed.
c. All doors off corridors are closed, including self closing fire doors.
d. Emergency shutdown procedures have been implemented, as needed, on "critical operations".

7. Floor Wardens having secured their respective floors shall proceed along the designated evacuation route to the designated emergency assembly area, and report their floor's status to the Building Warden.

8. After receiving status reports from each Floor Warden, the Building Warden shall inform the DC that the building is evacuated.

9. At this time the drill will be terminated, and all occupants allowed to re-enter the building.

POST DRILL EVALUATION

1. Performance criteria as employed in the Evacuation Training Program for Building and Floor Wardens shall be used as the drill standard.

2. The DC and support personnel shall assess the evacuation drill and document results on the Evacuation Drill Checklist which will be distributed. This form:

a. Documents evacuation times for each floor and the building as a whole.
b. Identifies performance highlights, areas for future action, and noted improvements.

POST DRILL CRITIQUE

1. A POST DRILL CRITIQUE SHALL BE CONDUCTED WITHIN ONE WEEK OF THE DRILL:

a. Scheduled and chaired by the Drill Coordinator.
b. Whenever possible, the critique will be held in the drill building.
c. Building and Floor Wardens, or their alternates, shall attend.

Appendix 13

BUILDING WARDEN DUTIES AND RESPONSIBILITIES

The following are the duties and responsibilities of each Building Warden. The cognizant office shall insure that selected Building Wardens are familiar with requirements. Appendix C of JPL's Multihazard Emergency Response Plan also covers building and floor warden duties and responsibilities.

1. Conduct periodic inspections of assigned building to ensure safety hazards are not present. Advise appropriate cognizant section Safety Coordinator of any discrepancies noted.

2. Develop and distribute to building occupants, an evacuation plan that includes a safe assembly area for building personnel. Assistance in developing a plan is available from the JPL Fire Department, the Laboratory Emergency Preparedness Administrator and the Occupational Safety Office.

3. The evacuation plan will designate primary and alternate evacuation routes. Elevators are not to be used as evacuation routes.

4. A diagram (JPL-wide standard design) showing primary and alternate evacuation routes shall be posted at central locations on each floor of the building to familiarize occupants with them.

5. The JPL Fire Department (JPLFD) shall conduct yearly fire evacuation drills to familiarize the building occupants with the sound of alarms and evacuation routes. Drills will also provide training for both building and floor wardens. Periodically, the Emergency Preparedness Administrator may initiate drills and exercises to insure that personnel are prepared to respond to different emergency scenarios.

6. Direct the efforts of the Floor Wardens and verify proper performance.

7. During an emergency: (on-Lab)
    a. Call the JPL emergency number, 911 (alternate 393-3333 if using a cellular phone), to report an emergency. Provide the operator the location of the emergency, and nature of it and your name. Stay on the line until the operator has recorded all pertinent information. Off-Lab

facilities will report emergencies as defined in their local emergency plan, and Part I, Section 6 of this manual.

b. . For identification, wear an orange bump hat.
c. Assure that all floors of the building are notified of the emergency, and if required, evacuate personnel to a safe area. If the evacuation alarms and emergency paging system are not operational, use the emergency bull-horns to initiate evacuation and to inform occupants of proper response procedures.
d. After evacuation, meet with floor wardens to verify all personnel have been evacuated.

8. Accompany JPLFD personnel and the cognizant section Safety Coordinator during yearly inspections, ensuring discrepancies are noted (corrected on the spot if possible) for early (within 30 days) correction.

9. At the close of each business day, verify that all fire doors are free of obstructions and are functioning properly; arrangements may be made with floor wardens or others, as appropriate.

10. Conduct meetings with floor wardens, at least semiannually, to discuss the emergency response posture of the building and occupants, offering possible solutions to existing problems. Provide a copy of the meeting minutes to the Laboratory Emergency Preparedness Administrator.

11. Be trained and certified to render CPR and First Aid . Building wardens should be trained in the use of fire extinguishers. In the event of a major emergency, and only after it has been determined safe by the JPLFD, be prepared to assist the JPLFD with search and rescue operations within the building, assisted by floor wardens and teams of building occupants.

12. Be trained in evaluating the condition of the building. If necessary and with the assistance of Facility Damage Assessment Teams, assess existing damage to the overall structure, and advise the Emergency Operations Center staff on the possibility to using the building as an emergency shelter.

13. Advise cognizant section Safety Coordinators when hallways, exits, etc., become congested with furniture supplies, trash or anything that would impede egress from the building.

FLOOR WARDEN DUTIES AND RESPONSIBILITIES

The following are the duties and responsibilities of each Floor Warden. The cognizant office shall insure that the selected Floor Wardens are familiar with requirements.

1. The Floor Warden is responsible for the indoctrination and training of personnel on assigned floors, to ensure proper action during emergencies. The following applies:

   a. Ensure emergency evacuation route diagrams are posted.
   b. Be completely familiar with floor plans, existence and location of hazardous materials operations, number of occupants and location of exits.
   c. Ensure that all occupants on the floor have a copy of the Building Evacuation Plan and are familiar with emergency procedures.
   d. Identify handicapped employees on floor. Devise a plan for their evacuation during emergencies, including the identification of personnel to assist the evacuation using the specialized evacuation chair. Be aware of personnel that may need assistance during an evacuation, i.e., personnel with injured leg, pregnant, or otherwise temporarily disabled.
   e. Be trained and certified to render CPR and First Aid. Floor wardens should be trained in the use of fire extinguishers. In the event of a major emergency, and only after it has been determined safe by the JPLFD, be prepared to assist the Building Warden and the JPLFD with search and rescue operations within the building using teams of building occupants.
   f. Be trained to assist the Building Warden and Facility Damage Assessment Teams in evaluating the condition of the building, to assess existing damage to the overall structure, and advise the Emergency Operations Center staff on the possibility of using the building as an emergency shelter.

2. Notify the cognizant office and the JPLFD of any flight hardware on floor and provide all pertinent information. Information concerning the type, location, and status of hazardous material operations must be passed on to both the JPLFD and Occupational Safety Office.

3. Know how and when to use fire extinguishers and their location. Arrange for hands-on training by the JPLFD for yourself and employees on your floor.

4. Be familiar with emergency alarm system and what to do if the alarms are not operational.

5. Conduct monthly walk-through inspections to verify that exits are clear of equipment, boxes, furniture or debris. Advise the Building Warden and the

cognizant section Safety Coordinator of any discrepancies that may impede egress from the building.

6. Conduct monthly checks of lighted exit signs and emergency lights, and report problems to Maintenance Control, 4-4933.

7. Conduct quarterly visual checks of fire extinguishers. Problems such as missing tags, seals and low pressure should be reported to the JPLFD, 4-3311.

8. Notify the building warden of incidents involving flight hardware and hazardous materials.

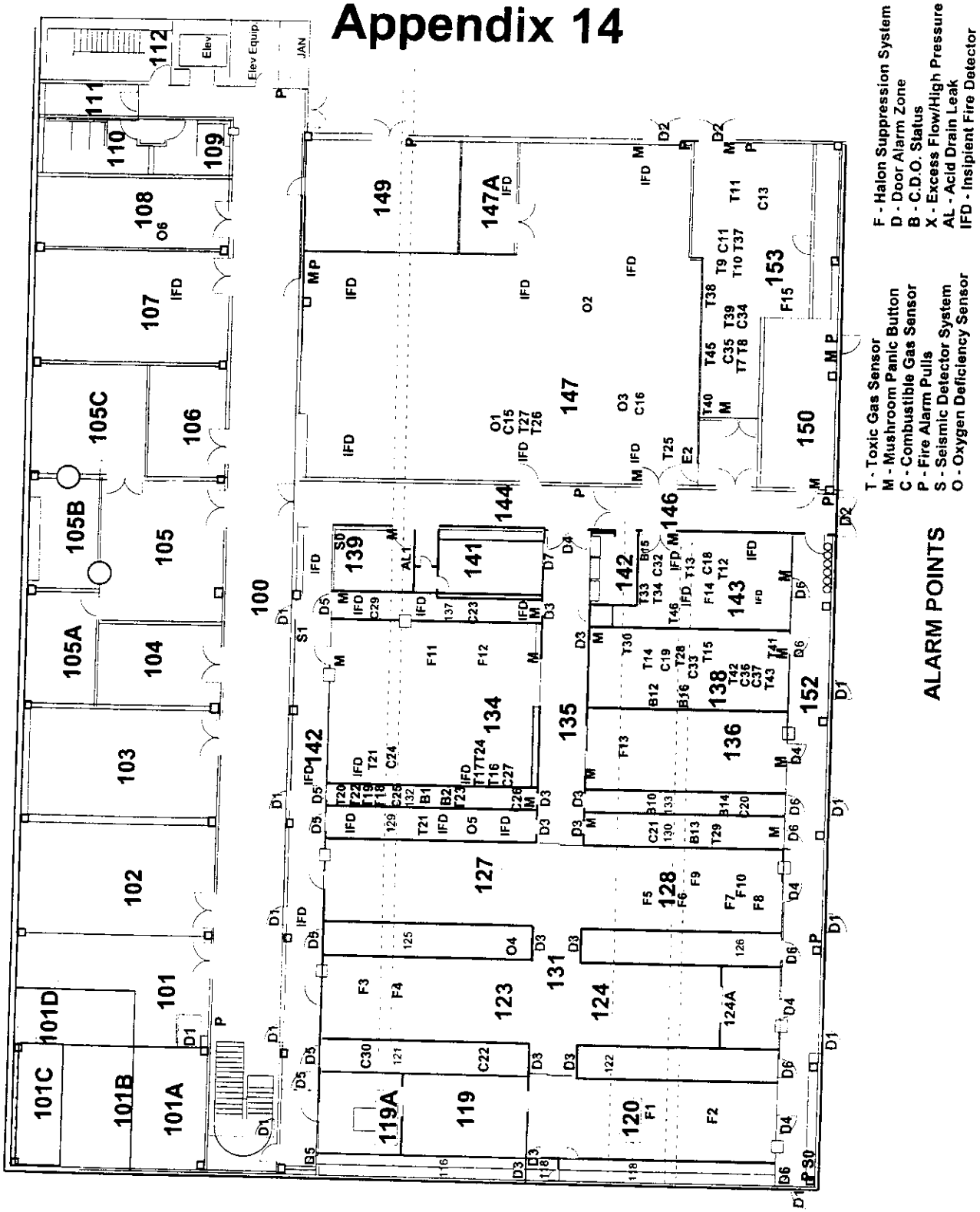
9. . During an emergency: (on-Lab)
   a. For identification, wear a yellow bump hat
   b. Call the JPL emergency number, 911 (alternate 393-3333 if using a cellular phone), to report an emergency. Provide the operator the location of the emergency, nature of it and your name. Stay on the line until the operator has recorded all pertinent information. Off-Lab facilities will report emergencies as defined in their local emergency plan, and Part I, Section 6 of this manual.
   c. Supervise the evacuation of personnel through established exits.
   d. Ensure all personnel on the floor are notified on an emergency and are evacuated, as required. All areas, including lavatories, offices, and conference rooms must be search to assure all personnel have evacuated. All doors must be closed when leaving an area.

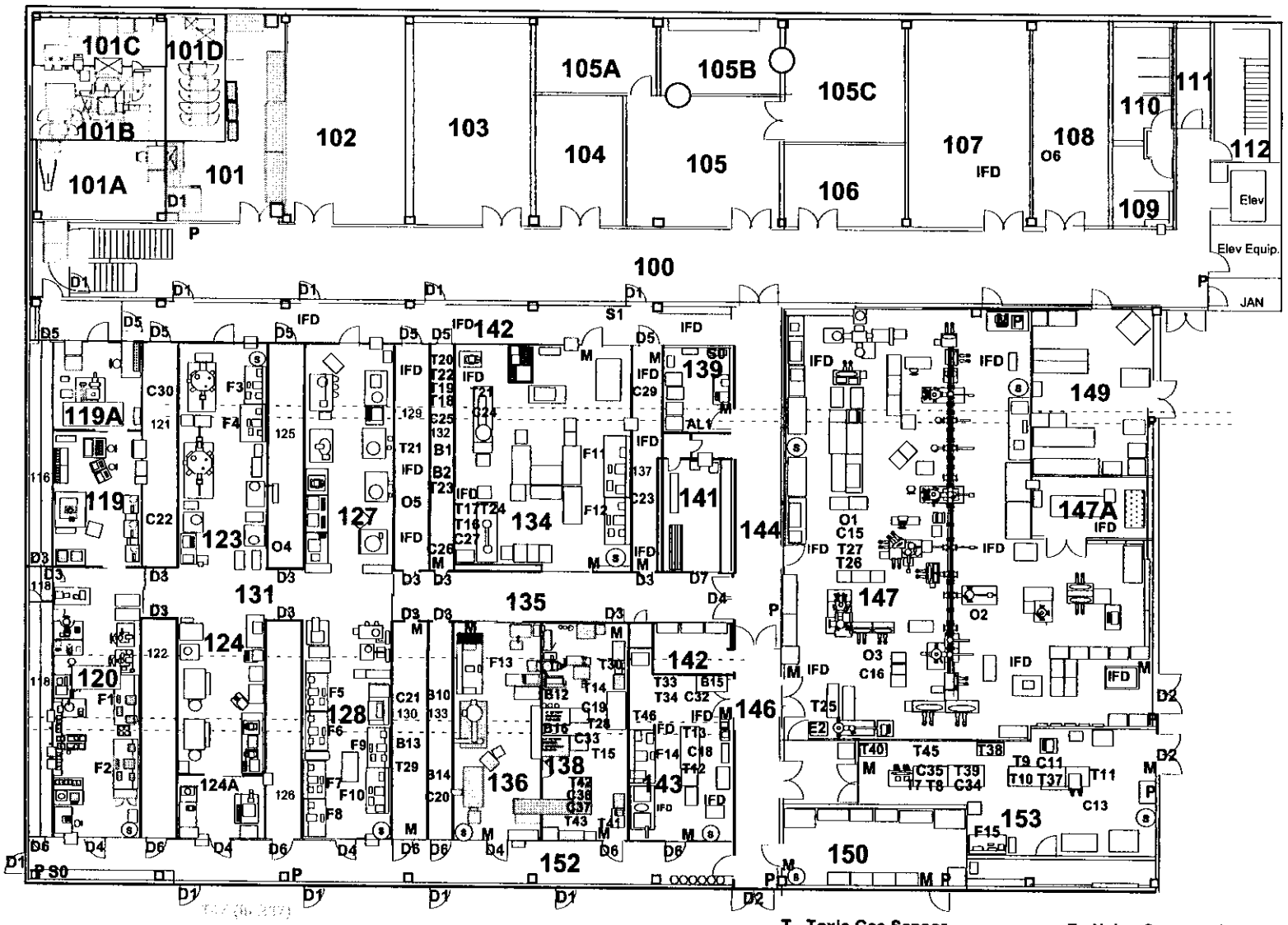
10.. Bomb Threats
If evacuation is necessary due to a bomb threat, warden should look for unusual objects (do not touch or move) in their areas as they evacuate. After evacuating, such items are to be reported to emergency personnel

11. Handicapped personnel will participate in yearly building evacuation drills.

12. At the close of each business day, assist the Building Warden to verify that all fire doors are free from obstruction and are functioning properly.

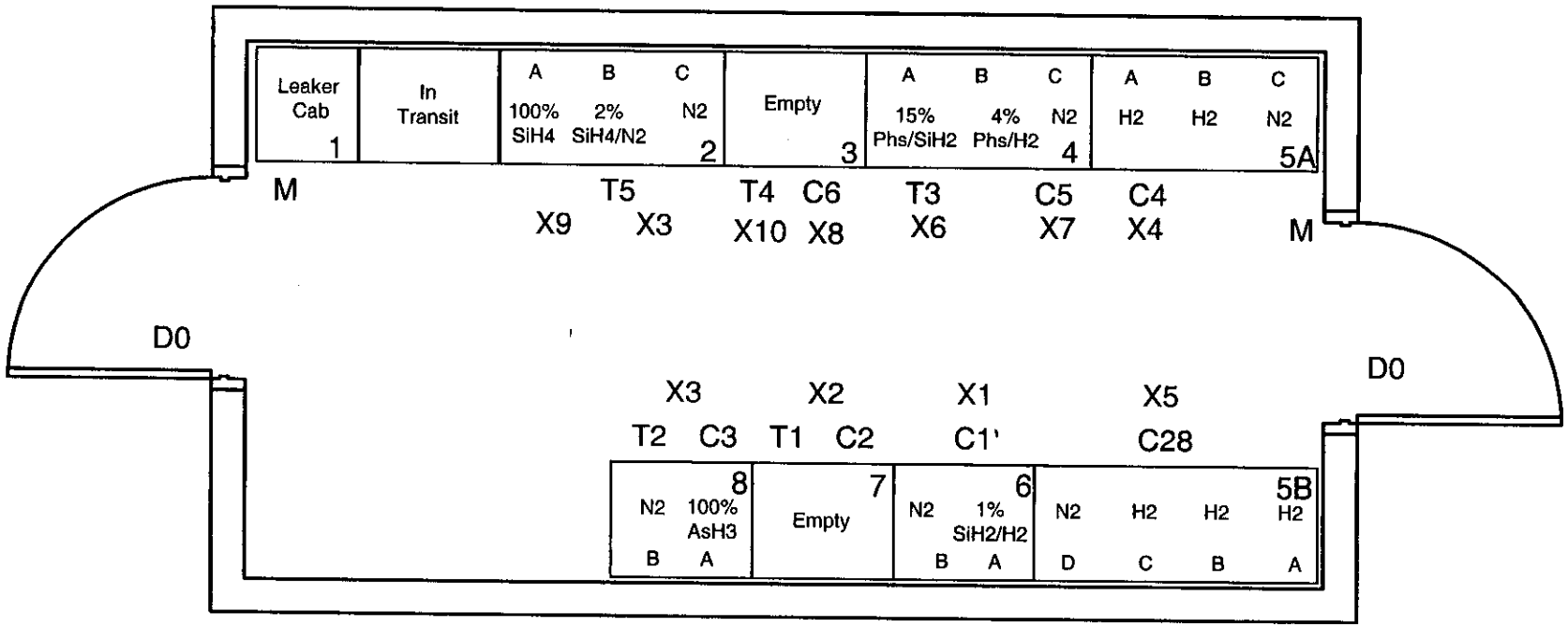
Appendix 14


ALARM POINTS
T - Toxic Gas Sensor
M - Mushroom Panic Button
C - Combustible Gas Sensor
P - Fire Alarm Pulls
S - Seismic Detector System
O - Oxygen Deficiency Sensor
F - Halon Suppression System
D - Door Alarm Zone
B - C.D.O. Status
X - Excess Flow/High Pressure
AL - Acid Drain Leak
IFD - Insipient Fire Detector



ALARM POINTS

HAZARDOUS GAS BUNKER



T - Toxic Gas Sensor
M - Mushroom Panic Button
C - Combustible Gas Sensors
D - Door Alarm Zone
X- Excess Flow / High Pressure

Appendix 15

ROTARY VANE VACUUM PUMP FLUID CHANGE PROCEDURE

The following pump oil procedure is to be followed for all rotary vane pump oil and inorganic fluid changes.

Pump operations involving chlorine (such as HC1, BC13, etc.) may produce phosgene. These operations require phosgene monitoring. If any phosgene is detected, operators are to leave the area and return only with appropriate protective breathing apparatus or request assistance from personnel authorized to use such equipment. NOTE: If phosgene is produced by pump operations involving chlorine, the effect will be localized around the pump opening and should not affect a large area.

1 AIR, OXYGEN AND INERT PUMPED MEDIA

If oxygen or a gas mixture containing an oxygen concentration above 50% is pumped in a unit not equipped with inert gas dilution, use an inert, oxygen-compatible pump fluid such as perfluorinated polyether (Fomblin or Krytox oil).

1.1 Protective Clothing

Wear chemical protective gloves (Nitride or equivalent).

Wear eye and face protection (monoshield or goggles with face shield).

1.2 Oil Change Procedure

If relocation of the pump is necessary to allow the oil to drain completely:

1. Disconnect inlet/outlet plumbing and cap off disconnect flanges at pump and plumbing.

2. Disconnect electrical connections.

3. Follow appropriate lifting guidelines.

Drain pump fluid into suitable receptacle. After draining, pour a small amount of fluid through pump to flush out residual contaminants.

Remove and replace oil filter.

Transfer waste fluid to a polyethylene container, seal tightly, label container "Hazardous Waste Used Pump Fluid." Double bag oil filter and label as above. A Waste Disposal Form (WDF) must be used.

Fill pump to proper level with correct type and viscosity pump fluid.

Reconnect pump and note date of oil change on pump tag.

2 PYROPHORIC AND COMBUSTIBLE PUMPED MEDIA

2.1 Protective Clothing

Wear chemical protective gloves (Nitrite or equivalent).

Wear eye and fact protection (monoshield or goggles with face shield).

Unless the operation is performed in an exhausted area, wear a respirator equipped with organic cartridges. Note: Personnel must be checked out for use of respirators prior to this operation (see Section 9.2.4).

2.2 Oil Change Procedure

Operate pump with all process gas flows stopped and with inert gas purging or ballasting of fluid case for one hour prior to stopping pump.

Verify that ambient temperature and pump temperature are not excessive prior to disconnecting pump plumbing.

Disconnect electrical connections.

Disconnect inlet/outlet plumbing and cap off disconnect flanges at the pump and plumbing.

Maneuver the pump to a position that will allow the fluid to drain completely.

Drain pump fluid into suitable receptacle. After draining, pour a small amount of fluid through pump to flush out residual contaminants.

Remove and replace oil filter.

Transfer waste fluid to a polyethylene container, seal tightly, and label container "Hazardous Waste -- Used Pump Fluid." Also, identify all known

contaminants. Double bag oil filter and label as above. A Waste Disposal Form (WDF) must be used.

Verify integrity of seals if fluid filtration system is coupled to pump with quick disconnect fittings. They could provide a source for air leakage.

Check radial shaft seals for leakage. This could also be a source for air leakage.

Check exhaust outlet, exhaust-side accessories, and outlet discharge line for blockage. This may cause overpressure in the pump fluid case, resulting in an expanded flammability range for flammable pumped media.

Fill pump to proper level with correct type and viscosity pump fluid.

Reconnect pump and note date of oil change on pump tag.

3. TOXIC AND CORROSIVE PUMPED MEDIA

3.1 Protective Clothing
Note: Personnel must be trained and authorized for use of NIOSH-approved supplied air respirators for this operation.

Wear chemical protective gloves (Nitrite or equivalent).

Wear eye and face protection (monoshield or goggles with face shield).

Wear total body coveralls (Tyvek or equivalent).

NIOSH-approved supplied air breathing apparatus.

3.2 Oil Change Procedure

Operate pump with all process gas flows stopped and with inert gas purging or ballasting of fluid case for one hour prior to stopping pump.

Disconnect electrical connections.

Disconnect inlet/outlet pumping and cap off disconnect flanges at the pump and plumbing.

For small pumps, transfer pump to a fume hood certified to have a minimum face air velocity of 150 feet per minute.

For large pumps, NIOSH-approved supplied air breathing apparatus must be worn.

Maneuver the pump to a position that will allow the fluid to drain completely.

Oil should be allowed to cool to room temperature prior to draining.

Drain pump fluid into suitable receptacle. After draining, pour a small amount of fresh fluid through pump to flush out residual contaminants.

Remove and replace oil filter.

Transfer waste fluid to a polyethylene container, seal tightly and label container "Hazardous Waste - Used Pump Fluid." Also, identify all known contaminants. Double bag oil filter and label as above. A Waste Disposal Form (WDF) must be used.

Verify integrity of seals if fluid filtration system is coupled to pump with quick disconnect fittings. They could provide a source for air leakage.

Check radial shaft seals for leakage. This could also be a source for air leakage.

Check exhaust outlet, exhaust-side accessories, and outlet discharge line for blockage. This may cause overpressure in the pump fluid case.

Fill pump to proper level with correct type and viscosity pump fluid.

Reconnect pump and note date of oil change on pump tag.

Check for fluid leaks regularly and oil level regularly.

If clothing becomes contaminated with pump fluid, double bag clothing and treat as hazardous waste.

4 GENERAL PRECAUTIONS

4.1 All surfaces in the process chamber, pumping system, and lines of plasma equipment may be contaminated with toxic or corrosive compounds.

4.2 Pump oils have been found to contain acidic contaminants.

4.3 Skin contact with contaminated surfaces and pump oils should be avoided.

4.4 When contact is necessary for maintaining the equipment, rubber gloves and eye protection are required. When handling oils or oil filters, arm guards, a face shield, eye protection, and a plastic apron should be worn.

4.5 Pump oils should be cooled to room temperature before draining to reduce any outgassing.

4.6 Manual cleaning of process chambers should be done using isopropyl alcohol (100%), Freon TF, Deionized (DI) water, or an industrial vacuum cleaner.

4.7 Cleaning of lines or internal pump parts should be performed under an exhausted fume hood or with appropriate respiratory protection and only by personnel specifically trained and authorized to use respiratory protection.

4.8 If a spillage of pump fluid occurs, keep away from open flames, heat sources, or hot surfaces Absorb spilled material with response pillows or pads and dispose of these as hazardous waste.

4.9 Thermal decomposition in air of perfluorinated polyethers may liberate hydrogen fluoride and carbonyl fluoride, both toxic.

4.10 Perfluorinated polyether fluid (Fomblin oil) is not recommended for systems using boron trichloride as a process gas because BC13 is suspected of causing the fluid to breakdown.

Appendix 16

CDO AND WET SCRUBBER MAINTENANCE PROCEDURES

1. CDO MAINTENANCE PROCEDURES

Controlled Combustion Decomposition Oxidation (CDO) units require periodic servicing, including replacement of heating elements and thermocouples Hydride gases reacted in the combustion chamber of the CDO unit form oxide particulates. In order to eliminate or minimize the possibility of exposure to oxide particulates during CDO service operations, the following procedure will be used.

1.1. Protective Clothing - Disposable Tyvek coveralls, disposable shoe covers, long-sleeve solvent gloves, goggles, and a half-face respirator will be used (for CDO units used with arsenic, a full-face respirator will be used). All personnel involved in this operation will be outfitted with the above-mentioned articles and trained in their use.

NOTE For CDO units that do not produce any hazardous byproducts, the service may be performed in place. In such cases, steps 2, 3, and 6 below may be skipped.

1.2. Exhaust Disconnection - The inorganic exhaust will be kept operational at all times. The KF flange on the upstream side, closest to the CDO unit, will be disconnected first. A blank off flange will be connected to the upstream side of the exhaust line first, then a second blank-off flange will be connected to the CDO side. Next, the KF flange on the downstream side, adjacent to the CDO, will be disconnected. A blank-off flange will be connected to the CDO side first, then one to the exhaust line.

1.3. CDO Removal - The unistrut sections attached to the CDO will be removed along with the CDO. Four half-inch hex bolts will be loosened in order to free the CDO from the remainder of the CDO support frame. The CDO will be lowered onto a cart, then transported into the arsenic hood in room 147.

1.4. Heater and Thermocouple Replacement - The heater and thermocouple will be replaced in accordance with the manufacturer's specifications. When work on the internal parts of the CDO is complete, new gloves will be donned. The used gloves will be considered contaminated waste. When the CDO is reassembled, all exterior surfaces will be wiped with a methanol-soaked wipe. The wipes and gloves used during the wiping will be considered contaminated waste. New gloves will be donned.

1.5. Material Disposal - All used gloves, wipes, mechanical fittings, and the used thermocouple and heating element will be double bagged and appropriately labeled, for example:

Hazardous Waste
Arsenic-contaminated wipes and gloves
(User's name)
7-28-2000

A hazardous waste disposal form will be filled out, and the JPL Environmental Affairs Office will be called to pick up this waste for off-lab disposal.

1.6. CDO Installation and Exhaust Hookup - The CDO will be secured to the support frame first. The exhaust will be connected in reverse order from that specified in step 3 above. The downstream side exhaust blank-off flange will then be removed first, then the CDO downstream blank-off flange. The CDO exhaust will then be secured to the building's exhaust line. This step will be repeated on the upstream side by removing the CDO blank-off first, then the equipment exhaust line blank-off. The equipment exhaust will then be connected to the CDO intake. A final wipe of all external surfaces will be performed with a methanol-soaked wipe. These wipes will also be considered contaminated waste and will be double bagged and treated as described in step 5 above. The CDO may then be tested for normal operation.

1.7. CDO Leak Testing - Prior to running hydride gas, leak checks will be performed on all mechanical plumbing connections. Where possible, this will be performed using H2 and an appropriate leak detector sensitive to at least 10 ppm.

1.8. CDO Overpressurization Capture Rings - In CDO applications utilizing toxic gases which might experience pressurization of the exhaust lines as determined through Haz-Op reviews (See Sec. 7), overpressurization capture rings should be provided on the KF flanges of the exhaust line connections to prevent O-ring expansion which might release toxic gas.

2. WET SCRUBBER MAINTENANCE PROCEDURES

2.1. Specific procedures have been developed for the maintenance of the toxic gas wet scrubbers associated with the MOVPEs in 302-153. They may be accessed electronically at http://mdlwww.jpl.nasa.gov/tools/CVD/Thomas-Swann/WetScrubberMaint.html and http://mdlwww.jpl.nasa.gov/ tools/ CVD/Aixtron/WetScrubberMaint.html.

2.2. Specific procedures have been developed for the maintenance of the building toxic gas wet scrubbers associated with the inorganic exhaust in the MDL Equipment Room, 302-236. They may be accessed electronically at http://mdlwww.jpl.nasa.gov/facility/InorgExhaustWetScrubber/Maintenance.html.

Appendix 17

AHM GAS PLUMBING
INTEGRITY VERIFICATION PROCEDURE

In the following procedure only perform a step once the previous step has been completed and passed. If a step is failed, the appropriate actions to repair the problem will be taken, then this procedure will be reinitiated. This form is to be filled out during the operation and maintained as a record.

Job name operation date

1. Evacuate and purge the inner process line 120 times by conducting two maintenance purge "2" (MP2) cycles on the semi-gas auto purge cabinet. The line is to be left with N2 in line at atmospheric pressure.

2 purge cycles completed (check off when completed)

Final Gage Pressure (0 to 10 psi) (Pass/ Fail)

2. Prior to cutting into line, take test sample from line and check with portable toxic gas sensor (MDA) to verify O ppb Hydride gas concentration. If other than O ppb concentration is detected, repeat step 1.

MDA Detector Readout (must be 0 to pass) (Pass / Fail)

3. On first cut into line, have portable sensor on hand to verify 0 ppb toxic gas level or equivalent.

MDA Detector Readout (0 to pass) (Pass/ Fail)

If a nonzero condition is detected, leave the area immediately and contact the MDL Safety Engineer or his alternative.

4. Do primary line welds with orbital welder and purge gas running.

5. Outboard Gross Leak Test - Interior Line

Upon completion of primary line (inner line to carry toxic gases) welds, pressurize with N2 to approximately 200 psig. Record time, pressure, and temperature inside and in bunker.

Wait a minimum of 48 hours, then record time, pressure, and temperature. The system must maintain better than a 1 x 10-1 Scc/sec leak rate in order to pass (per Section 15370 of original building construction specifications for MDL -- SR No. 85-5032, Spec. No. ss-132).

Date Date

Time Time

Interior Temp Interior Temp

HGB Temp HGB Temp

Starting Pressure Ending Pressure

Leak Rate (must be (1x10-2 standard cubic centimeters per minute)

Pass/Fail

6. Inboard Fine Leak Test - Interior Line

Perform this test only after passing the Outboard Gross Leak Test.

The helium leak detector must be certified to be properly calibrated and in complete working order.

- Entire system will be evacuated through an oil-free calibrated helium leak detector to the 10-s Torr range.

- Test all valves and new welds by spraying exterior with helium and recording leak rates or pressure changes.

The system will pass if there is no single leak greater than 1.0 x 10-5 Scc/sec and if the total of all leaks in the system shall not exceed 3.2 x 10-5 Scc/sec (as per Section 15370 of original building construction specification -- See 5).

Evacuated Line Pressure

All single leaks below 1.0 x 10-5 Scc/sec. Pass/ Fail

Total System Leak Rate . Pass/Fail

7. Outer stainless steel jacket of coaxial line will then be welded while maintaining pumps on inner primary line (for final leak testing verification).

8. Outer Jacket Gross Leak Test

Upon completion of outer jacket welding, an attempt will be made to slightly pressurize this line (to 2-5 psig) by plugging end of line in gas cabinet source and injecting nitrogen gas. The new joints will be grossly verified for integrity with a liquid bubbler (such as SNOOP or equivalent).

Pass/ Fail

9. Final Interior Line Leak Verification

Upon passing Outer Jacket Gross Leak Test described above, a final inner line system leak test will be made by flowing helium through outer jacket, slightly pressuring (to 2-5 psig) as in 8 above (but with helium) and monitoring oil-free leak detector on primary line to have < 3.2 x 10-5 Scc/sec leak rate. [< 6 x 10-8 SCC/sec desirable].

Helium Pressure on Outer Jacket

Inner Jacket Leak Rate Pass/ Fail

10. Upon successfully passing all of the above, the line may be repressurized with the hydride gas and placed into service.

Verified by

Name
Signature
Date

Appendix 18

REQUEST FOR DIRECT USE OF MACHINE SHOP EQUIPMENT AS AN AUTHORIZED MDL USER

Personnel may request to directly use machine shop tools and equipment located in the Tech Shop in bldg. 103 for the support of MDL / JPL programs as an authorized MDL User. Financial support for this service access is provided through the MDL User fee structure. Prior to the start of work, he/she must complete this form, obtain line management concurrence, and be fully aware of the machine shop safety policies. He/she will comply with any request related to safety of personnel or equipment made by the Machine Shop Coordinator / Cognizant Engineer. After hour key access may also be requested for the Tech. Shop area through this form, but requires approval by both the Sec 357 Shop Coordinator / Cognizant Engineer and the Sec. 357 Manager prior to issuing a key request. After hour use of major machine shop tools requires the use of the buddy system.

USER NAME _____ SEC _____ DATE _____

USER SIGNATURE _____ DATE _____

USER'S GROUP SUPERVISOR _____ DATE _____

USER'S SECTION MANAGER _____ DATE _____

MDL MANAGER _____ DATE _____

Equipment Checkout completed (Required for equipment utilization):

Equipment	Shop Coordinator/Cognizant Engineer	Date

Custodian of record: MDL Machine Shop Coordinator / Cognizant Engineer

MDL 1736 R 1/01

ADDITIONAL REQUEST FOR AFTER HOURS KEY ACCESS TO MACHINE SHOP TECH AREA:

USER NAME _____ SEC _____ DATE _____

USER SIGNATURE _____ DATE _____

USER'S GROUP SUPERVISOR _____ DATE _____

USER'S SECTION MANAGER _____ DATE _____

MANAGER, SECTION 357 _____ DATE _____

Appendix 19

MICRODEVICES LABORATORY

Safety Guidelines
For
JPL Facilities/Maintenance Personnel, Outside Contractors and Visitors
(Rev. 03/19/2001)

The Microdevices Laboratory (MDL) is a state-of-the-art semiconductor and superconductor research and development facility. By its very nature, this necessitates the use of hazardous production materials (HPMs) and acutely hazardous materials (AHMs) (e.g. toxic, flammable and corrosive chemicals and gases), high voltage, and expensive high technology equipment. Areas, equipment, and processes are highly monitored. All monitoring systems are linked to the fire alarm system for building evacuations. The fire alarm system will be used to clear the building for toxic spills, oxygen deficient atmospheres, chemical incidents, as well as fires. Evacuation assembly points have been reviewed to be at safe, upwind locations under most conditions. For your safety, the safety of others working at MDL, and the protection of processes and equipment, the following safety rules must be followed before accessing the facility or any equipment in MDL for maintenance or other operations.

FOR CLEARANCE AND/OR QUESTIONS, THE CENTRAL POINTS OF CONTACT ARE EITHER:

- **THE MDL SAFETY ENGINEER:** **Amy Posner, @ 4-9635**
- **THE MDL FACILITIES ENGINEER:** **Hugo Velasquez, @ 4-0079**
- **THE MDL MANAGER:** **James L. Lamb, @ 4-5019**

FUNDAMENTAL RULE: ALWAYS ASK IF YOU DO NOT KNOW.

OUTSIDE CONTRACTOR RESPONSIBILITIES:

- **Know the building evacuation procedure:**
  - Stop work.
  - Leave the facility by the nearest exit.
  - Go to the assembly point.
  - Check in with your MDL contact.
  - Remain at the assembly point until instructed to return to the building.

- **Know what the building evacuation enunciator sounds like:**
  - The MDL Safety Engineer will demonstrate what the alarm sounds like.
  - All alarms of a sufficiently high level are tied into the MDL Fire Alarm system for evacuations.

- **Know what to do in the event of an earthquake:**
  - Stop work.
  - Get away from chemical operations and other hazards.
  - Get under a desk, table or a doorway.
  - Once the shaking stops go to the evacuation assembly area.

- **Know what to do in a medical emergency:**
  - If you are injured or become ill and need emergency medical treatment, go to the nearest phone and call 911 (or dial 393-3333 if using a cellular phone).
  - Give your name, your location (building - room), and nature of the injury.
  - Inform or your MDL point of contact about the emergency.

- **Know how to report a fire:**
  - Go to the nearest phone and call 911 (or dial 393-3333 if using a cellular phone) or pull the fire alarm pull station or emergency mushroom button.
  - Evacuate the area and go to the evacuation assembly area.
  - Remain at the assembly point until instructed to return to the building.

- **Know what to do in the event of a chemical spill or gas release:**
  - Evacuate the area immediately.
  - Phone the JPL emergency number 911 (or dial 393-3333 if using a cellular phone).

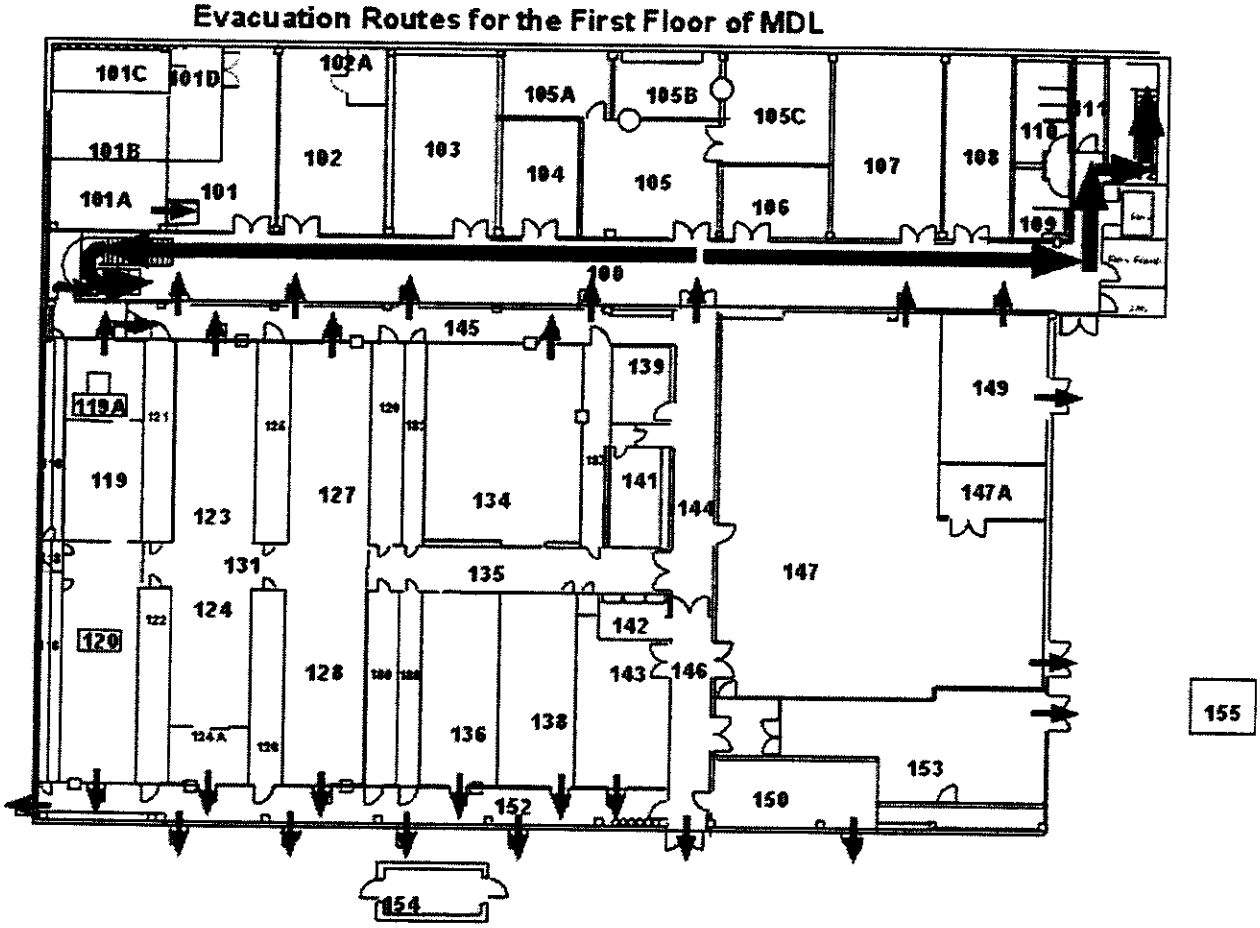
- **Know the required reporting and clearance procedures:**
  - Log in with your MDL contact prior to beginning work and log out when done.
  - Inform your MDL contact of all procedures to be followed.
  - Prior to beginning work, obtain the necessary clearances from the JPL Safety Office for all chemicals to be utilized and brought into MDL and inform the MDL Safety Engineer of their planned use.
  - Always have a copy of the material safety data sheets for chemicals which you or your company are supplying. Provide a copy to the MDL Safety Engineer.
  - Provide safe storage for these chemicals if they are on-site more than one day.
  - Never close a valve, throw a switch or perform any action if you have not discussed and received clearance from your MDL point of contact.

JET PROPULSION LABORATORY RESPONSIBILITIES:

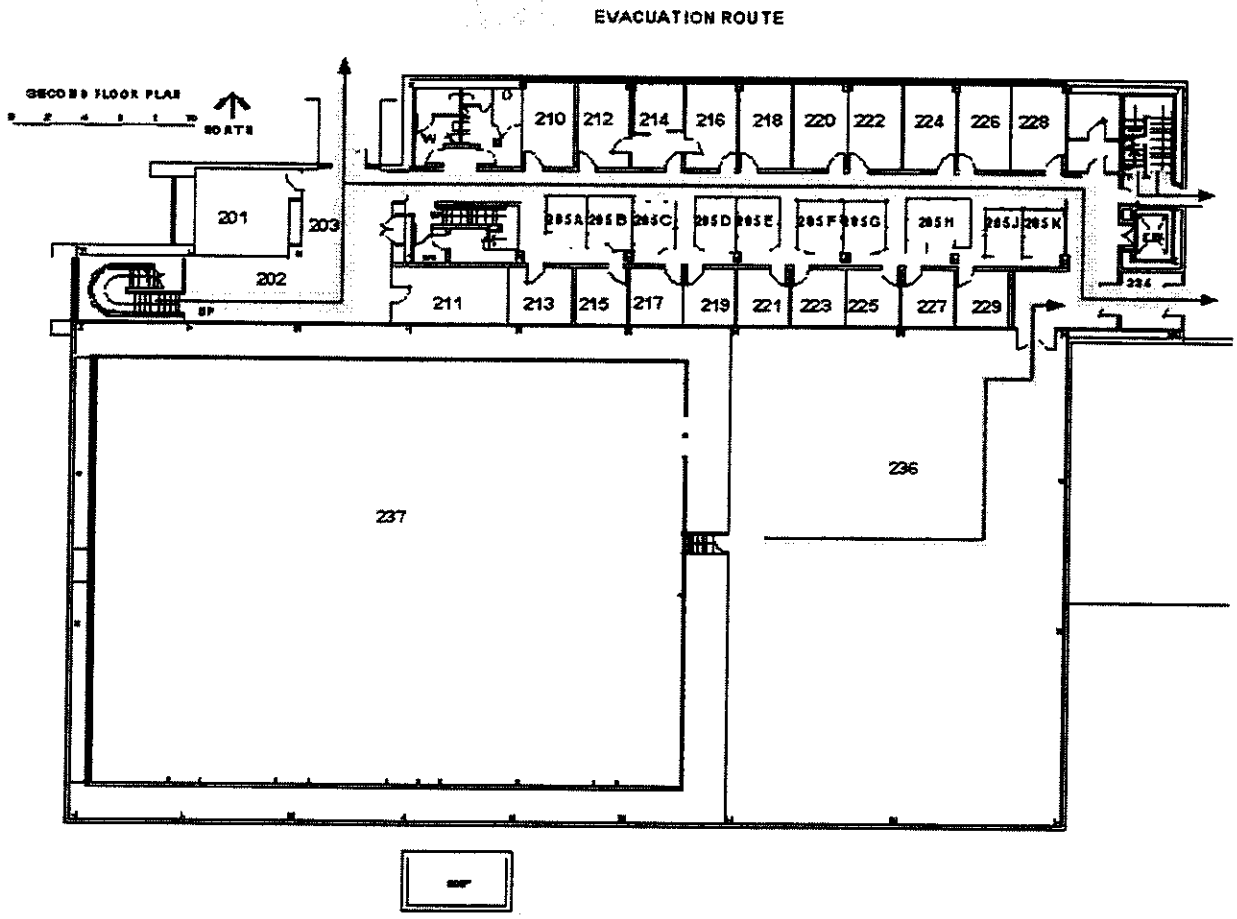
The MDL Safety Engineer will be responsible for providing outside contractors and their employees instructions related to:

- Hazards and hazardous chemicals to which they may be exposed while on the job site.
- Measures that the contractor employees may take to lessen their possibility of exposure.
- Steps that have been taken to lessen the risks of exposure.
- The location of MSDSs for all hazardous chemicals.
- Procedures to follow if the contractor is exposed.

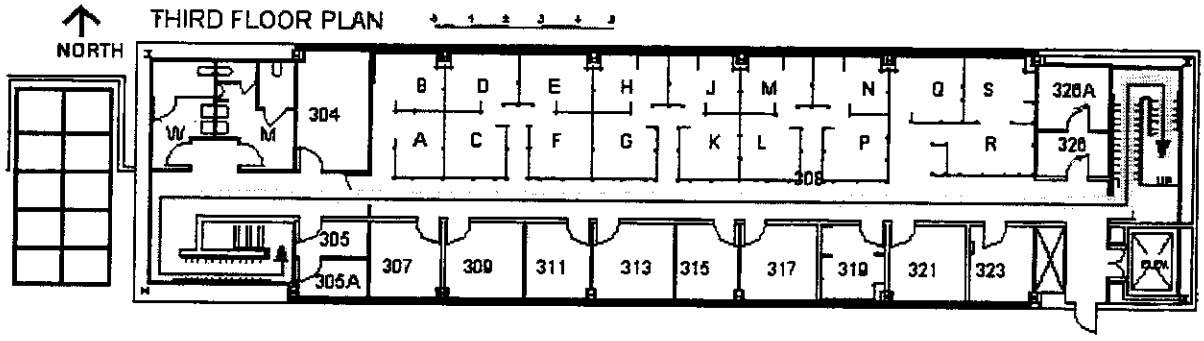
MATERIAL SAFETY DATA SHEETS ARE AVAILABLE OUTSIDE OF THE MDL LIBRARY, 302-211.



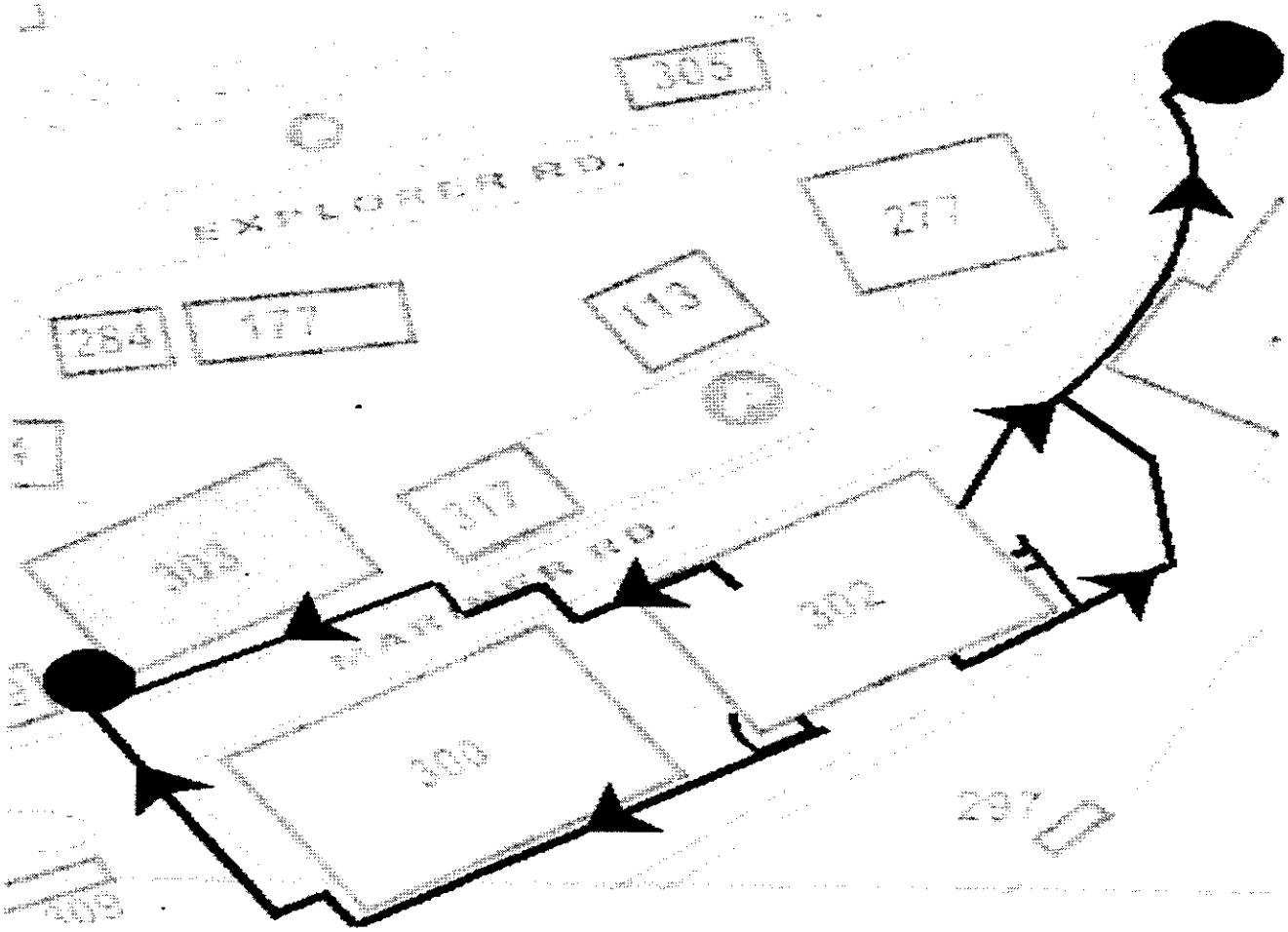
Evacuation Route for the First Floor of MDL



Evacuation Route for the Second Floor of MDL



Evacuation Route for the Third Floor of MDL



Microdevices Laboratory (B302) Evacuation Routes and Assembly Areas

I hereby certify that I have read and understand the Microdevices Laboratory Safety Guidelines for JPL Facilities/Maintenance Personnel, Outside Contractors and Visitors

Signature: _____

Print Name: _____

Section/Company: _____

Date: _____

Return this form to the MDL Safety Engineer (302-215) or the MDL Manager (302-219) prior to beginning work in MDL.

Appendix 20

EXAMPLES OF INCOMPATIBLE CHEMICALS

Substances in the left hand column should be stored and handled so that they cannot accidentally come into contact with corresponding substances in the right hand column under uncontrolled conditions.

Chemical	Is Incompatible With
acetic acid	chromic acid, nitric acid, perchloric acid, peroxides, permanganates
acetic anhydride	Hydroxyl-containing compounds such as ethylene glycol and perchloric acid
acetylene	chlorine, bromine, copper, fluorine, silver, mercury
acetone	concentrated nitric and sulfuric acid mixtures
alkali and alkaline earth metals	water, carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide, halogens
ammonia (anhydrous)	mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid (anhydrous)
ammonium nitrate	acids, powdered metals, flammable liquids, chlorates, nitrates, sulfur, finely divided organic or combustible materials
aniline	nitric acid, hydrogen peroxide
arsenical materials	any reducing agent
azides	acids
bromine	see chlorine
calcium oxide	water
carbon (activated)	calcium hypochlorite, all oxidizing agents
carbon tetrachloride	sodium
chlorates	ammonium salts, acids, powdered metals, sulfur, finely divided organic or combustible materials

Chemical	Is Incompatible With
chromic acid and chromium trioxide	acetic acid, naphthalene, camphor, glycerol, alcohol, flammable liquids in general
chlorine	ammonia, acetylene, butadiene, butane, methane, propane or other petroleum gases, hydrogen, sodium carbide, benzene, finely divided metals, turpentine
chlorine dioxide	ammonia, methane, phosphine, hydrogen sulfide
copper	acetylene, hydrogen peroxide
cumene hydroperoxide	acids (organic and inorganic)
cyanides	acids
flammable liquids	ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens
fluorine	everything
hydrazine	hydrogen peroxide, nitric acid, any other oxidant
hydrocarbons (e.g., propane, butane, benzene)	fluorine, chlorine, bromine, chromic acid, sodium peroxide
hydrocyanic acid	nitric acid, alkali
hydrofluoric acid (aqueous or anhydrous)	ammonia (aqueous or anhydrous)
hydrogen peroxide	copper, chromium, iron, most metals or their salts, alcohols, acetone, organic materials, aniline, nitromethane, combustible materials
hydrogen sulfide	fuming nitric acid, oxidizing gases
hypochlorites	acids, activated carbon
iodine	acetylene, ammonia (aqueous or anhydrous), hydrogen
mercury	acetylene, fulminic acid, ammonia
nitrates	sulfuric acid
nitric acid (concentrated)	acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases, copper, brass, any heavy metals
nitrites	acids

Chemical	Is Incompatible With
nitroparaffins	inorganic bases, amines
oxalic acid	silver, mercury
oxygen	oils, grease, hydrogen, flammable liquids, solids, or gases
perchloric acid	acetic anhydride, bismuth and its alloys, alcohol, paper, wood, grease, oils
peroxides, organic	acids (organic or mineral), avoid friction, store cold
phosphorus (white)	air, oxygen, alkalis, reducing agents
phosphorus pentoxide	alcohols, strong bases, water
potassium	carbon tetrachloride, carbon dioxide, water
potassium chlorate	sulfuric and other acids
potassium perchlorate (also see chlorates)	sulfuric and other acids
potassium permanganate	glycerol, ethylene glycol, benzaldehyde, sulfuric acid
selenides	reducing agents
silver and silver salts	acetylene, oxalic acid, tartaric acid, ammonium compounds, fulminic acid
sodium	carbon tetrachloride, carbon dioxide, water
sodium nitrite	ammonium nitrate and other ammonium salts
sodium peroxide	ethanol and methanol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethyl acetate, methyl acetate, furfural
sulfides	acids
sulfuric acid	potassium chlorate, potassium perchlorate, potassium permanganate (and similar compounds of light metals such as sodium, lithium)
tellurides	reducing agents

[Source: The University of Texas at Austin Lab Safety Manual, Appendix VIII, November, 1996. Author: ehs@www.utexas.edu]

Appendix 21

USEFUL PHONE NUMBERS

NOTE: This appendix is included for reference in the printed version of this document. It is updated with each new version, but the most up-to-date version of the emergency phone list will be found at http://mdlwww/safety

TO REACH EMERGENCY RESPONDERS AT JPL:

***** In Case of Emergency, dial 911 *****

(IF USING A CELLULAR PHONE, DIAL 393-3333)

Other safety contacts include:

- Amy L. Posner (MDL Safety Engineer) 4-9635
  - Michael M. Martinez (MDL Safety Technician) 4-9865
  - Patricia L. Patterson (MDL Safety Technician) 3-2529
- James L. Lamb (MDL manager) 4-5019
- JPL Fire Department 4-3311
- JPL Medical Services 4-3319
- JPL OSO (Occupational Safety Office) 4-4711
- JPL EAO 4-0180
- JPL Security 4-4160 console 4-3530

The MDL Support Staff is further defined with contact information at the MDL Support Group Web Page.

FIRST FLOOR PHONES

Room 101	MEMS Electrical Characterization	4-9643
Room 101A	E-Beam Lithography Lab	4-7470
Room 102	E-Beam Lithography Support	4-9646 (Dan Wilson) 4-2118 (Paul Maker)
Room 103	MDL Support	4-1331 (Keith Fields) 4-0079 (Hugo Velasquez) 4-0411 (James Wishard)
Room 104	Sample Preparation	4-9650
Room 105	Testing Lab	4-7870
Room 105A	Low Temperature S/T Microscopy	4-9649
Room 105B	Darkroom	4-9651
Room 105C	Transmission Electron Microscopy	4-9397
Room 106	Scanning Electron Microscopy	4-9398
Room 107	Optoelectronic Characterization	4-9399
Room 108	IR Characterization	4-8324
Room 119	E-Beam Lithography Lab	4-7470
Room 120	PhotoLithography Lab	4-4414
Room 124	SEM & Metallization Lab	4-4576
Room 127	Metallization Lab	4-4576
Room 134	Amorphous Silicon/PECVD Lab	4-4136
Room 136	Thermal Processing Lab	4-4660
Room 138	Thermal Chase	4-4660
Room 139	Monitoring & Control Center	4-7890
Room 142	Chemical Entry	4-2078
Room 143	Polishing & Lapping, Electroplating Lab	4-2078
Room 147	Molecular Beam Epitaxy /XPS/ Tunnel Microscope Lab	4-7940 3-2680 3-2679
Room 149	Nano / Bio Lab	4-4849
Room 150	Chemical Preparation	4-2078
Room 153	Chemical Vapor Deposition	4-2162